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TECTONIC STRUCTURE OF NORTHERN ANDES IN COLOMBIA AND VENEZUELA[1]

HENRY DE CIZANCOURT[2]
Paris, France

ABSTRACT

The Andean chain is divided in Colombia and Venezuela into several branches.

The aim of the present article is to show that certain of these branches correspond with a folded geosynclinal zone, whereas other branches correspond with a block-faulted foreland. The Maracaibo Lake depression is interpreted as a "Median mass" intercalated among the folded Cordilleras.

Finally, the problem of the mutual independence of the Peruvian, Colombian, and Venezuelan folds is discussed and the writer concludes that the Colombian and Venezuelan Andes do not form an extension of the Peruvian folds.

INTRODUCTION

A part of the Andean chain situated north of the equator, that is, within the territories of Colombia and Venezuela, shows a particular structure in that it is subdivided into several branches separated by depressions. In Colombia these branches are: the Coastal Cordillera, the Western Cordillera, the Central Cordillera, and the Eastern Cordillera. The latter range, upon reaching the Venezuelan territory, is again subdivided into the Sierra de Perija and the Sierra de Merida. The intra-Andean depressions, separating these branches, are those of San Juan Atrato, Cauca, Magdalena, and the depression of the Maracaibo Lake.

It seems that the nature and origin of these various elements, which together form the Northern Andes, is not uniform, and that some of them have a geologic history altogether different from that of the neighboring elements.

[1] Manuscript received, March 7, 1932; revised, December 28, 1932.

[2] Chief geologist, Compagnie Francaise des Petroles, 9, Square de Messine.

In this article an attempt is made to study the part played by these various elements, from the stratigraphic as well as from the tectonic viewpoint, and particularly to make a distinction between those elements the origin of which is due to a folded geosynclinal sedimentation zone, and those which are connected with rigid and faulted forelands.

Several points of the interpretation adopted in this article are different from those which have been previously proposed. The writer hopes that even though his interpretation may be modified in the future, it will have reached its aim if it forms a basis for further discussions of this problem.

The present article is based partly on personal observations obtained during a rapid trip to Venezuela in 1929, and partly on the study of the existing geologic literature, particularly of the already old works of Hettner, Sievers, Karsten and Wolff, and the more recent publications of Steinmann, Stutzer, Grosse, Hubach, Sheppard, Liddle, and others, a detailed enumeration of which will be found in the bibliography.

The writer is glad to take this opportunity to express his sincere gratitude to all who have facilitated his trip to Venezuela, as well as to his travelling companion, H. H. McKee. Finally, he wishes to thank W. P. Haynes and A. Miller, who have undertaken the translation of this article.

PRINCIPAL SUBDIVISIONS OF ANDEAN SYSTEM

In the Northern Andes the history of the Alpine orogenic movements practically had its beginning during the Lower Cretaceous period, when the Andean geosyncline originated.

In this way, the distribution of the Cretaceous deposits allows us to make a first distinction between the zones which belonged to this geosyncline and those which remained outside of it.

The Cretaceous deposits are very unequally developed and do not everywhere show the same facies in various parts of this general area: the maximum thickness is reached in the Eastern Cordillera of Colombia, in the Venezuelan Andes, and in the Sierra de Perija. In all these regions the Cretaceous deposits are represented by marine, fossiliferous formations, such as shales, sandstones, and limestones, which have formed a very thick sedimentary series filling the geosynclinal basin. The following figures are intended to give a general idea regarding the thicknesses observed. These figures do not include the red sandstone series (Giron beds), the geologic age of which may extend from the Permian to the Cretaceous.

An altogether different development took place in the Central Cor-

dillera of Colombia, in the Western Cordillera, and in the Sierra Nevada de Santa Marta.

		Approximate Feet
Eastern Cordillera	Southern Colombia	6,000*
Eastern Cordillera	Magdalena	3,300†
Eastern Cordillera	Central part	18,000–21,000‡
Sierra de Perija		2,400§
Sierra de Perija		2,000– 5,500‖
Sierra de Merida		7,000‖

* Grosse. † Harrison. ‡ Engster. § Sievers. ‖ Liddle.

All the authors agree that Cretaceous deposits are almost completely lacking in these areas, and that at numerous points Tertiary deposits lie unconformably over the basement rocks. However, some Mesozoic porphyrites are known in these regions, and Grosse has stated that Lower Cretaceous ammonites are present in marine intercalations within these porphyrites in the region of Antioquia. Therefore, it seems probable that a part of Mesozoic porphyritic tuffs, porphyrites, et cetera, which developed in the Western Cordillera and in the Sierra Nevada, may represent an eruptive facies of the Lower Cretaceous period.

Thus, the unit formed by the Central Cordillera, the Sierra Nevada, and the Western Cordillera has a geologic history entirely different from that of the Eastern Cordillera: these regions represent the border of the Cretaceous geosyncline, a zone the larger part of which remained above the sea-level during the Cretaceous period, inasmuch as Cretaceous deposits are found only on the edges of this zone and are represented only by an eruptive facies.

Therefore, the distribution and the facies conditions of the Cretaceous deposits indicate a division of the Northern Andes into two parts: (1) a geosynclinal zone in the Eastern Cordillera and (2) continental areas which border this zone on the west. The contrast existing between these two zones has already attracted the attention of several observers, and, in particular, has been recorded by Stutzer and Sievers.

In order to again find Cretaceous deposits it is necessary to go as far as the Coastal Cordillera and the northern part of the Western Cordillera. In the first of these regions Hubach has reported the presence of very thin (100 meters) marine Cretaceous formations with traces of ammonites. In the second region he observed much thicker Cretaceous deposits (1,000 meters), the presence of which in this region will be explained later.

These stratigraphic considerations clearly indicate that the branching of the Colombian Andes does not correspond with a simple division of one folded mountain chain into several branches, but that this

system of branched chains is composed of several elements, each of which has had an independent geological development and is accordingly distinct from a stratigraphic point of view.

MASSIFS OF WESTERN FORELAND

This independence between the branches of the Northern Andean system is proved not only by their stratigraphic composition, but also by the tectonic structure of the various elements of this system.

The Eastern Cordillera is a folded chain, compared by Engster to the Franco-Swiss Jura Mountains. Its folds are due to a compression of the previously mentioned geosynclinal basin, that is, of a zone where the crust offered little resistance and could therefore be affected plastically by this compression. The folds are inclined toward the east on the eastern flank and toward the west on the western flank.

This structure shows that the geosynclinal basin was compressed between two rigid massifs, one of which was the Llanos foreland in the east, and the other the Central Cordillera in the west.

In this way, the Central Cordillera, which from a stratigraphic standpoint appeared as a continental area, acted as a rigid block from a tectonic standpoint, and the contrast is very sharp between the compressed folds of the Eastern Cordillera and the enormous block of crystalline and Paleozoic rocks, which extend from Magdalena River to Cauca River.

De Böckh arrives at a similar interpretation when he admits that "parts of the Central Cordillera and of the Western Cordillera played the rôle of a 'Median mass' "[1] in the Andean folds. Towards the north the Central Cordillera extends across the down-faulted Banco zone and its continuation is formed by the Sierra Nevada, several isolated outcrops forming the connection. Here again Sievers insisted on the contrast existing between the folded zone of the Sierra de Perija with its well developed Cretaceous deposits, and the compact block of the Sierra Nevada, where Cretaceous deposits are almost unknown, with the exception of some minor outcrops along its northern border. On this occasion Sievers has described the crushing of the Sierra de Perija folds against this obstacle.

Recently, Joleaud also adopted this interpretation, but proposed to extend it to the crystalline cores of the Eastern Cordillera and of the Sierra de Merida, which, as demonstrated above, can not be done, inasmuch as these crystalline rocks seem to form the cores of Cretaceous folds and do not have the character of outside masses included

[1] H. de Böckh, G. M. Lees, F. D. S. Richardson in J. W. Gregory, *The Structure of Asia* (London, 1929), p. 165.

in these folds. Finally, after a recent exploration of the Sierra Nevada, S. Weigner[1] came to the conclusion that this massif does not belong to the Andean folds, thus confirming the interpretation of Sievers.

Opinions have greatly varied as regards the part played by the Goajira Peninsula. By some this peninsula has been considered to be an extension of the Sierra de Perija, but Stutzer has shown the contrast existing between the considerable thickness of Cretaceous deposits within the Montes de Oca, which form the northern extremity of the Sierra de Perija, and their very small thickness in the Goajira region. Moreover, the folds of the Sierra de Perija, striking northeast, change their direction near the Goajira, and turn toward the east and even east-southeast.

For these various reasons, it would seem preferable to consider the Goajira as belonging to the same general system as the Sierra Nevada.

The relation between the folds of the Eastern Cordillera and the border region of the Central Cordillera is clearly explained in the works of Grosse, as regards Southern Colombia, and in the works of Hubach and Stutzer, as regards the Magdalena valley. They show that the folds of the Eastern Cordillera strike northeast, whereas the border of the Central Cordillera extends north-northeast or north, so that in fact the folds strike obliquely toward the border, and, when coming from south to north, it can be observed how the extension of these folds is successively stopped by this border. Therefore, it can not be said that they form branches of and detach themselves from the Central Cordillera, as, on the contrary, their development is stopped by the crystalline massif. This is an example of the classical case described by Argand of a group of folds pressed against an obstacle and striking obliquely toward it.

Thus, the same conditions prevail along the entire border of the Cretaceous geosyncline: the extension of folds which originated within the geosyncline was stopped by rigid massifs, which during the folding period acted as obstacles; these are the Central Cordillera, the Sierra Nevada, and the Goajira.

The extension of this zone toward the east is more difficult to follow, inasmuch as the contact of the various elements is hidden by the sea. Probably this extension can be looked for in the Paraguana Peninsula and the islands bordering the northern part of the Venezuelan coast. The Paraguana Peninsula was considered by Sievers as a prolongation of the Sierra de Perija beyond the Maracaibo depression, but this does not seem probable, because of the analogy of its structure with that of the Goajira on the one hand, and the Aruba and

[1] Oral communication.

Curacao islands on the other hand. This analogy has already been mentioned by Sievers, and, more recently, by Liddle. The east-west, or even east-southeast or west-northwest strike of the Cretaceous formations in the Goajira region, confirms this interpretation. From a tectonic standpoint the east-west extension of the extremity of the Sierra de Perija and its continuation toward Taos Island involves the existence of a barrier on the north formed by the Goajira, the Paraguana, and the islands of Aruba, Curacao, Bonaire, et cetera.

The question which then arises is to determine whether the massifs situated on the western border of the geosyncline should be considered as "Median masses" included among the Andean folds, or whether they belong to the foreland of the latter. It is difficult to solve this problem, but the following statement can be made.

The Western Cordillera is distinguished from the Central Cordillera only by a greater development of Mesozoic igneous rocks and they are separated from one another by the Cauca valley. According to the recent researches of Stutzer and of Grosse there can be no doubt as to the fact that the Cauca valley is a down-thrust valley. A series of faults cuts it into a number of secondary horsts and grabens. Thus there is no organic difference between the Central and Western cordilleras: they are separated fragments of one tectonic unit.

Toward the north, some complications appear, which have been described in the interesting studies of Hubach. The Western Cordillera is divided into several branches, the continuation of one of which, extending under the depressed valley of the Atrato, is the Panama Cordillera. It disappears in the sea somewhat northeast of Colon. Another less developed branch extends along the left side of Sinu; finally, the last one forms the ridge between Sinu and San Jorge; it continues in the Carmen de Bolivar region by a system of Tertiary folds.

Whereas the depression of the lower course of the Cauca, as well as that of the Banco region, corresponds to a simple morphological depression of the crystalline basement filled by Neogene and recent sediments, but slightly disturbed,—Cretaceous and Tertiary deposits are developed in the region between the Uraba Gulf and the Sinu, which have been closely pressed into a system of very acute folds by pressure from the bordering massifs.

Not much can be said about the Coastal Cordillera, the crystalline core of which extends from Garachine to Gorgona Island and is covered by only slightly developed sedimentary formations. On the contrary, Neogene and Quaternary deposits are well developed in the large depression of the Choco.

Thus, in all the region situated between the Eastern Cordillera and the Pacific Ocean, that is, in the Central, Western, and Coastal cordilleras, the same stratigraphic conditions prevail: the crystalline basement is exposed in large areas, Cretaceous deposits are only slightly developed, or even completely absent, with the exception, however, of the depressed zone of Uraba Bay, where deeper conditions prevailed, and Tertiary and Quaternary formations unconformably and directly overlie the crystalline basement and fill the depressions.

Therefore, there is no reason whatever to consider this system as other than a rigid foreland, a continental basement, which forms the western part of the framework of the Andean geosyncline. However, this basement has been affected by a system of dislocations, this being the origin of the intra-Andean depressions of Rio Magdalena and Rio Cesar, of Rio Cauca, and of Rio San Juan and Rio Atrato.

This general interpretation seems to correspond more accurately with the various facts observed rather than the hypothesis of Suess, which is still being frequently repeated and according to which these various elements are diverging branches, originating from a single trunk. The foregoing interpretation seems also to be preferable to the theory of de Böckh—exposed in a rather unexplicit manner—and according to which the unit formed by the Central and Western cordilleras seems to be an old geanticline, parts of which acted later as a "Median mass."

The Magdalena depression has been considered by Stille as a rift valley, and this interpretation has recently been adopted by Harrison. In fact, however, the location of this depression coincides with the border between the folded zone and its foreland, and therefore belongs to the type of large depressions, which, for instance in the Alps, extend between the Alpine folds and the foreland massifs, such as the Rhone valley. As demonstrated by Stutzer and later by Grosse, the Cauca valley corresponds in fact with a rift valley, which separates the two parts of one unit formed by the Central and the Western cordilleras. The mutual relation existing between these two massifs is confirmed by the fact that they join north of Antioquia.

The detailed studies of Grosse have revealed the presence of westward thrusts in the Cauca downthrust and also the fact that the border faults plunge east. It must therefore be admitted that the origin of this trough is connected with tensions and disruptions which in turn were due to effects of the Andean folding. The Alpine foreland again supplies examples of similar cases: for instance, the Limagne trough in the Central Massif in France, and the Rhone rift valley are due to

analogous phenomena. The presence of volcanoes in both cases only confirms this analogy. In spite of this, the dislocations of the Cauca region appear to be much more important and, in the same way, the volcanic phenomena, the distribution of laccolites, et cetera, are much more intense.

On the contrary, the depression of the Lower Cauca, as well as that of the Banco, which continues the former, seems to correspond with a simple plunge of the crystalline basement, unconformably covered by Upper Tertiary and Quaternary deposits. This plunging movement is possibly connected with a system of transverse faults, as has been admitted by Harrison.

The depression of the San Juan and Atrato rivers also seems to correspond with another terrace of the foreland, the dislocations of which seem to have played an important part in the localization of volcanic phenomena, whether old (Mesozoic) or recent.

In summary, it can be stated that according to the writer's interpretation, the Andean system can be subdivided into two principal zones: (1) a geosynclinal basin, which became a zone of subsidence during the Lower Cretaceous period and which has been folded by the successive Andean movements during the Upper Cretaceous and the Tertiary epochs into a series of tight folds. This area is a plastic zone of the crust, bordered on the east by a foreland represented by the Llanos plateau, which forms the edge of the Brazilian shield, and on the west by (2) a western foreland representing a rigid continental area, where the effects of the movements which affected the geosynclinal zone brought about breaks and dislocations, which subdivided this foreland into a series of blocks separated by depressions.

Thus this system would in certain ways appear as a homologue of the Bolivian plateau and would be an example of what Staub called "randliche Zwischengebirge," that is, the deformed border of continental areas. But whereas the Bolivian plateau shows structures thrust and overthrust toward the east, the corresponding elements in Colombia are thrust toward the west, which is quite normal in consideration of their symmetrical location with regard to the geosynclinal axis.

Toward the south, the Central and Western cordilleras extend through the territory of Ecuador, showing a similar structure, that is, a zone of Mesozoic basic igneous rocks in the west, a down-faulted area in the center, which is filled here with volcanic products, and a crystalline zone in the east. This system continues as far as 5° South latitude, where it disappears at the Peruvian frontier. On the south there is only a zone of tightly pressed Andean folds, as has been shown

by Steinmann. These folds, striking first north-northwest, turn west between 9° and 5° South latitude, forming the Andes of Chimu, which

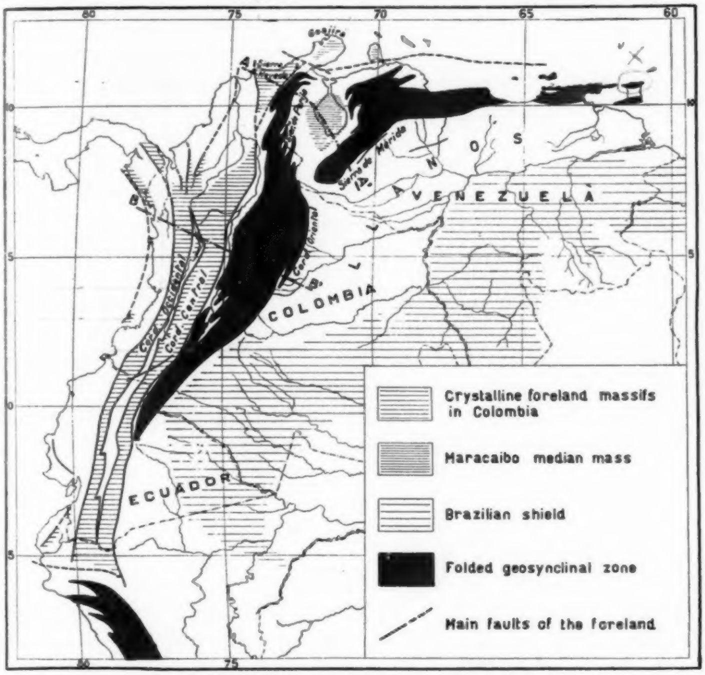

FIG. 1.—Tectonic sketch of northern Andes. Folds of northern Peru, only schematically drawn. AA' and BB': cross sections, Figure 2.

in this way are located south of the crystalline massifs of Colombia and Ecuador. The strike of the folds is west-northwest; it is perpendicular to the general trend of the crystalline massifs.

This confirms the independence of the north-northeast striking

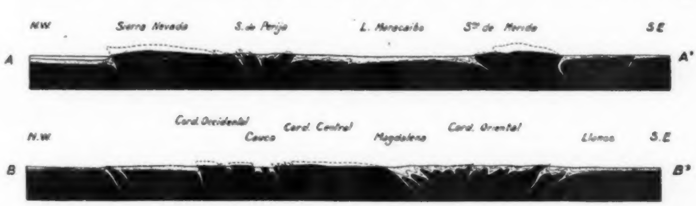

FIG. 2.—Schematic cross sections. For location, see Figure 1.

faults of this latter group from the folds striking northeast in the Eastern Andes of Colombia, and west-northwest in the Chimu Andes.

The Amotape massif should be included in the system formed by the crystalline massifs of Colombia and Ecuador, as indicated by its block-faulted tectonic structure, where faulting prevails, affecting the oil-bearing regions of northern Peru and Ecuador.

BRANCHING OF MARACAIBO LAKE

The second of the Andean branchings is the one which affects the Eastern Cordillera of Colombia, dividing it into two branches separated by the topographic depression of Lake Maracaibo.

The explanations of this phenomenon have varied considerably according to different authors. Hettner considers that this depression is a down-faulted area, whereas according to Sievers and Hubach it corresponds with an axial plunge of the folds located between Rio Catatumbo and Rio Zulia, these folds reappearing in the Falcon region. Liddle is of the opinion that the Maracaibo Lake corresponds with a geosynclinal basin surrounded by structures plunging toward the north on the western flank and toward the south on the eastern flank, due to a rotational movement of orogenic forces. Staub was the first to admit the existence of a deep buried massif, or "Zwischenmassiv," which would have divided the Eastern Cordillera into two branches.

As already explained, the system formed by the Eastern Cordillera in Colombia and the Sierra de Perija and Sierra de Merida in Venezuela corresponds with a folded zone of a geosynclinal character. Stratigraphically this system is characterized by the presence of very thick deposits, few of which, however, are deep-sea deposits. Many of them belong to the type of Flysch deposits, very similar to the Alpine Flysch, and are due, as are the latter, to a sedimentation in a gradually subsiding basin. In general, this type of deposits is poor in fossils, but such fossils as have been found clearly belong to the Mediterranean-Alpine type, as has already been demonstrated by Haug and Collet.

The important point which should be specially emphasized is that these deposits indicate a relatively plastic zone of the crust, which was sinking continuously during the Cretaceous period until the time when it was folded due to the compressive action of the forelands. It is probable that a part of the crystalline basement had already formed several geanticlinal ridges, and in this connection Hubach shows the facies differences of the Cretaceous deposits between the western and the eastern parts of the Eastern Cordillera.

Toward the south the intensity of the folding decreases and simul-

taneously the entire series loses gradually its geosynclinal character. Recent explorations of Sinclair and Wasson in Ecuador showed that the thickness of Cretaceous deposits is reduced here to less than 2,000 feet. Moreover, above the Cretaceous formations appears the continental facies of the Puca formations, which are mainly developed on the Bolivian plateau. This is the southern extremity of the geosyncline.

From a tectonic standpoint the Eastern Cordillera of Colombia forms a group of tightly pressed folds, most of which show only Cretaceous formations. However, some of them are sufficiently uplifted and eroded to show outcrops of the Paleozoic crystalline basement. The maximum width of this tectonic unit is located between 4° and 6° North latitude and it strikes northeast. Between 6° and 8° the folds turn north, and due to the upward trend of the axes the basement rocks crop out in the region of Ocana-Pamplona-Bucaramanga. These folds continue in the Catatumbo basin, and after curving northeast, where crossing the Venezuelan border, they turn again north, according to a very remarkable disposition which can be seen in the anticlines of Buena-Esperanza, Rio de Oro, Rio Tarra, and Cucuta.

The Sierra de Perija appears north of Catatumbo and continues the preceding zone, showing a well pronounced *en échelon* structure. At 11° North latitude, instead of extending toward the Goajira, as the geographical disposition seems to indicate, the Sierra de Perija turns abruptly east and, farther on, even east-southeast, toward Taos Island, where the same strike can be observed.

The Sierra de Merida appears in the vicinity of San Cristobal and extends as far as Barquisimeto. It is separated from the Eastern Cordillera by the Tachira depression, which is filled with Lower Tertiary deposits and shows some Cretaceous anticlines (Rubio, Lobatera).

The Sierra de Merida does not seem to be a direct continuation of the Eastern Cordillera for the following two reasons.

The first reason is the difference in the tectonic style existing between these two chains: indeed, the Eastern Cordillera is formed by a series of tightly pressed folds, showing *en échelon* structure, and the crystalline cores of which appear at some places in the form of narrow outcrops. On the contrary, the Sierra de Merida is a large anticlinal arch, a large ground-fold the crystalline core of which forms one block and extends as far as Barquisimeto with a maximum width of 100 kilometers.

The second reason is that the Cretaceous folds of the Tachira depression, striking northeast, north, and north-northwest, do not seem to continue directly either the Cucuta folds or the ground-fold of the Sierra de Merida.

Thus, although a connection at depth between the crystalline basement of the Eastern Cordillera and of the Sierra de Merida is evident, it seems that these two systems have been folded independently. The Tachira depression corresponds with a zone where the two systems of folds had been mutually stopped.

The explanation of this structure can be obtained by the study of the Maracaibo Lake depression.

This depression is bordered on its western and northern sides by the Sierra de Perija and its prolongation toward Taos Island, on its southeastern side by the Sierra de Merida, on the south by the plunging ends of the folds located between Rio Catatumbo and Rio Zulia, and on the east by the extremity of the Falcon folds.

In the south, the folds which strike from south to north plunge toward the north, as already mentioned.

In the east, the Falcon folds, which generally strike northeast, curve toward the south where approaching the Lake of Maracaibo, and their extremities plunge in a southward direction. This disposition is well marked in the anticlines of El Tigre, Muralla, Mene Grande, Motatan, to mention only the principal ones.

Thus, as has been well pointed out by Liddle, the folds on the southern and southwestern border of the lake are curved toward the north, whereas the Falcon folds are curved toward the south.

This structure can not be explained either by the presence of a fractured area, or by an axial plunge, as the folds on the two shores of the lake are not continuous with each other.

In order to explain this, it would be necessary to know the structure of the central part of the lake, but this is unfortunately impossible inasmuch as very thick Upper Tertiary and Quaternary deposits cover here the older formations. Therefore, a general indication as to the structure of this region can be obtained only by studying the form of the folds.

The explanation suggested in this article admits the presence of a rigid massif, "Zwischenmassiv," or "Median mass," under the depression of Maracaibo Lake, this massif remaining included among the folds of the geosyncline as an inert mass.

Therefore, this massif would have played a part similar to that of the Hungarian massif, located between the Alps and the Carpathian Mountains. Like the latter, it is hidden by Upper Tertiary deposits in a depression bordered by folded chains.

The presence of this "Median mass" permits us to explain in a very simple way all the individual tectonic phenomena observed in the structures which border the lake.

Figure 3 shows the location of the various tectonic zones: the geosynclinal basin being compressed between two forelands in the east and in the west, the displacement of which is indicated by arrows.

The presence of the Maracaibo massif within the folded area gave rise to two zones where the compression reached its maximum: these two zones are now the Sierra de Merida and the Sierra de Perija. This interpretation is confirmed by the fact that the folds of the southeastern border of the Sierra de Merida (Barinas) are inclined toward the southeast, whereas the folds of the northwestern border are inclined toward the northwest.

Now it can be understood why the Sierra de Merida, being a new anticlinal structure, acted as an obstacle against the development of the folds of the Eastern Cordillera. The Tachira depression corresponds with a zone where the two systems of folds met.

The Sierra de Perija is a continuation of the Eastern Cordillera with *en échelon* structure, which is so common in this part of the Cordillera. The folds of the Eastern Cordillera, located in the southwestern corner of the Maracaibo Lake depression, are inclined toward the east, which indicates an equal eastward movement of the folds. It is now clear how their further extension was stopped by the southwestern border of the Maracaibo massif and why they were obliged to change their original strike into a north-south strike.

At the same time, the compression which formed these folds was less strong in the vicinity of the border of this massif, and, in consequence, these folds gradually disappear toward the north. This structure corresponds with what is called "virgation du second genre" by Argand.

The structure of the northeastern corner of the lake can be explained in the same manner. In this region the folds are inclined toward the north or the northeast, which indicates a thrust in the same direction. The northeastern border of the Maracaibo massif stopped their movement and curved their extremities toward the south. Exactly as the folds of the southwestern corner of the lake and for the same reasons, the folds of the northeastern corner gradually disappear where approaching the massif.

It is useless to discuss further the mechanism of these tectonic movements, which are shown on Figure 3.

The great thickness of sedimentary deposits which cover the Maracaibo massif (which is proved by the wells drilled on the western shore of the lake) may be suggested as opposed to the foregoing interpretation. However, other examples of the same kind are known; for instance, several depressions located within areas of folded chains corre-

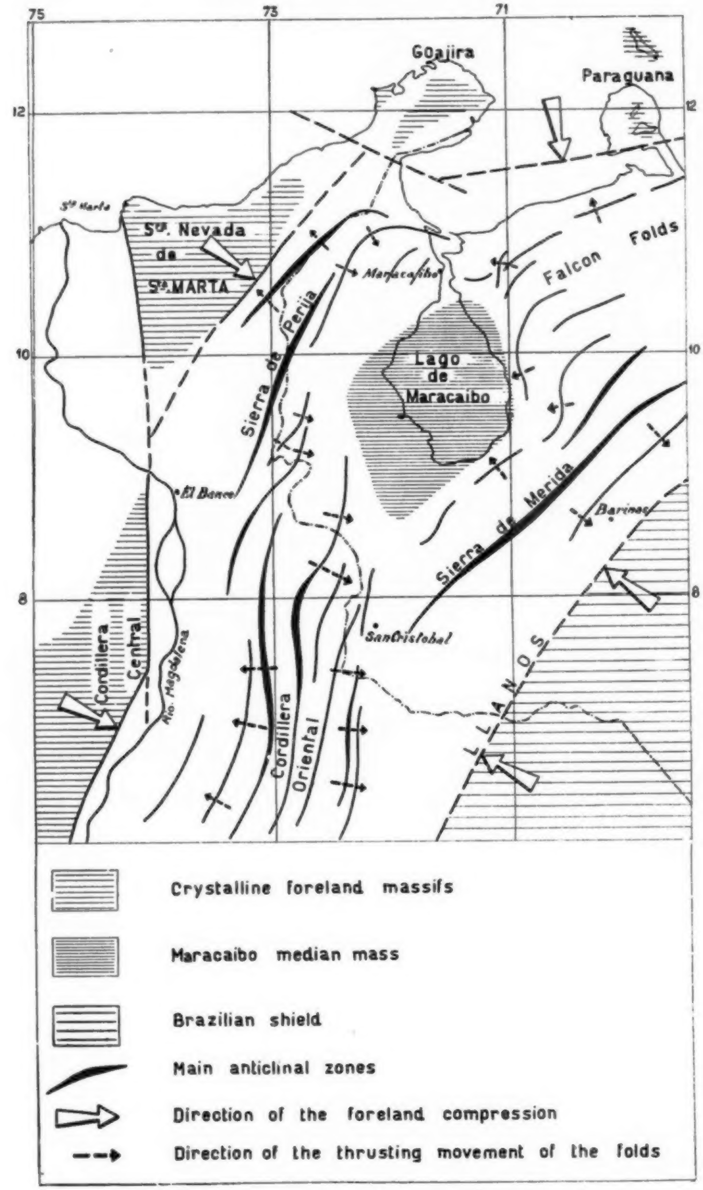

FIG. 3.—Tectonic sketch of Maracaibo Lake depression.

spond with deep massifs, such as the Hungarian massif between the Alps and the Carpathians, the downthrusts of the Mediterranean, and the Tarim depression in central Asia. The great thickness of Upper Tertiary and Quaternary deposits, covering the Maracaibo massif, is, therefore, not an argument against its existence, and it should be noted that the Maracaibo Lake depression offers at present more or less the same aspect as the Pannonian (Hungarian) depression during the Upper Miocene.

The depth to which the Maracaibo massif did sink seems to be considerable, judging by the thickness of the sedimentary cover. This can probably be explained by a tendency toward an isostatic equilibrium, corresponding with the great elevation of the crystalline cores in the Sierra de Merida and in the Sierra de Perija.

However, a direct confirmation of the suggested interpretation could be obtained only by means of geophysical measurements.

CONCLUSIONS

In summary, the interpretation of the tectonic structure of the Northern Andes proposed in this article, is as follows.

In the Northern Andes there are three principal and distinct tectonic elements.

1. A geosynclinal zone is located within the area of the Eastern Cordillera of Colombia, the Sierra de Perija, the Sierra de Merida, and the Caribbean Cordillera. This zone is characterized by a very thick sedimentary series and has been folded first during the Upper Cretaceous period and again during the Middle and Upper Tertiary periods. Toward the south, within the territory of Ecuador, this zone gradually loses its geosynclinal character.

2. In the center of the geosynclinal zone, a rigid massif occupies the depression of Lake Maracaibo and is bordered by folded chains mentioned under 1.

3. The orogenic movements which folded the geosynclinal zone affected also the tectonic structure of the western foreland, which, in consequence of these movements, was divided into a series of blocks—horsts and grabens—separated by a system of faults, some of them being parallel with the edge of the geosynclinal zone, whereas others strike diagonally.

Toward the south this dislocated foreland ends at 5° South latitude. In this area it prevents the further normal extension of the Peruvian Andes and provokes their curving toward the northwest, that is, toward the Pacific Ocean, where they disappear (Chimu Andes).

Thus the branching of the Andes is a purely morphologic phe-

nomenon and it is due to the juxtaposition of folded elements of a geosynclinal origin and of faulted elements belonging to a rigid foreland. Moreover, there is no continuity between the folded zones of Peru, Colombia, and Venezuela: the Peruvian Andes end at 5° South latitude, and their extremity is formed here by the Chimu Andes; the Eastern Cordillera of Colombia is an entirely new chain, the extremity of which is formed by the Sierra de Perija; the Sierra de Merida is again an independent unit, which originates in the region of San Cristobal and the continuation of which is formed by the Caribbean Andes extending as far as the island of Trinidad.

This tectonic structure is clearly reflected in the type of the covering rocks. The dislocations and fractures which divide the foreland massifs in Colombia and Ecuador were utilized by the Mesozoic and Tertiary volcanic eruptions, whereas in the folded geosynclinal zones there are no volcanic phenomena and these zones show only marine formations.

The problem of the distribution of petroleum reserves is not discussed in this article, but it should be noted that there is a direct relation between the petroleum occurrences and the tectonic and stratigraphic zones, as here subdivided. All the large oil occurrences of Colombia and Venezuela are located on the borders of the folded geosynclinal area, corresponding with a zone of rapid sedimentation in a gradually sinking basin.

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RESERVOIR ROCKS OF PERSIAN OIL FIELDS[1]

G. M. LEES[2]
London, England

ABSTRACT

The paper gives a description of the reservoir rocks of three fields, Masjid-i-Sulaiman, Haft Kel, and Naft Khaneh. The reservoir rock is a limestone of Lower Miocene age called the Asmari limestone. It is a fine-grained foraminiferal limestone, mostly of low porosity, and the porosity of the rock is independent of the degree of dolomitization. Fracturing of the rock is the most important factor governing production.

INTRODUCTION

Three fields have been developed in Persia up to the present: Masjid-i-Sulaiman and Haft Kel near the head of the Persian Gulf, and Naft Khaneh on the Iraqi-Persian frontier northeast of Baghdad. The production of the last named field has not been important, as it has been limited to the requirements of local markets. Masjid-i-Sulaiman has been producing continuously since 1911 and has yielded 58,000,000 tons to date. Haft Kel has produced 4,000,000 tons since production started at the end of 1929.

The reservoir rock of all three fields is limestone. That of Masjid-i-Sulaiman and Haft Kel is the Asmari limestone, a thick-bedded foraminiferal limestone of Lower Miocene age. At Naft Khaneh the equivalent formation has been given the local name of Kalhur limestone.

This paper describes the general characteristics of these Lower Miocene reservoir limestones, as it is from these rocks that the bulk of the Persian production has been drawn up to date. Oil in quantity has also been struck in the Eocene under the Masjid-i-Sulaiman Asmari limestone field, but as yet no heavy production has been drawn from this horizon.

SUMMARY OF GEOLOGICAL HISTORY

Sedimentation persisted almost continuously in the southwestern Persian geosyncline from later Paleozoic until the Pliocene. Up to the

[1] Manuscript received, November 14, 1932. Published by kind permission of the chairman and directors of the Anglo-Persian Oil Company, Ltd.

[2] Chief geologist, Anglo-Persian Oil Company, Ltd., Britannic House, Finsbury Circus.

end of Eocene time, the deposits were predominantly calcareous: limestones and marls. During the Oligocene and early Miocene the geosynclinal sea became more limited in extent, chemical deposits made their appearance, and eventually great thicknesses of anhydrite and salt were laid down throughout the long belt of country from the mouth of the Persian Gulf to northern Iraq, a distance of about 1,000 miles. At first the lagunal conditions were comparatively local and temporary, but by the end of Lower Miocene time the formation of anhydrite, salt, and shale had become more continuous and exceedingly widespread. The deposits of this age have been named the Lower Fars. In Middle Miocene time, a freshening of the sea allowed the formation of shelly limestones and marls over wide areas, but in many cases these are associated with anhydrite beds. A gradual withdrawal of the sea followed and estuarine and terrestrial deposits were formed. The sandstones and shales of the Upper Miocene are called the Upper Fars and the sandstones and conglomerates of the Pliocene, the Bakhtiari. The principal folding movements began in the Miocene and reached their greatest intensity in the Pliocene. They resulted in the formation of long narrow folds of great size.

STRUCTURAL POSITION OF OIL FIELDS

The oil fields are situated in a "foothill" zone of the Zagros arc. The high mountain front lies about 20 miles northeast of Masjid-i-Sulaiman and Haft Kel, and the mountains proper consist of tightly packed folds of Mesozoic and Paleozoic rocks. Still farther northeast are the great overthrust sheets or nappes.

The Tertiary rocks occupying the foothill zone are thrown into a series of long parallel folds, the detail of which is much complicated by the incompetence of the anhydrite-salt Lower Fars formation. Most of the anticlinal axes are marked at intervals along their length by crest maxima or elongated domal structures. For example, Asmari Mountain and Masjid-i-Sulaiman are two crest maxima on one axis separated by a simple saddle. At Asmari Mountain the limestone rises to a height of over 4,000 feet above sea-level, whereas at the oil field its highest point is just above sea-level.

The earth movements causing folding acted from the northeast and anticlines formed are mostly asymmetrical, the southwest flank being the steeper. The southwest flank of Asmari Mountain is faulted and the intensity of the pressure has caused many small faults and local crumpling of the limestone. It will be seen in a later section of this paper that the shattered condition of the limestone at Masjid-i-Sulaiman is a most important factor in its function as a reservoir rock.

Naft Khaneh is situated in an area where the folding was less intense and the anticlines are separated by broader and simpler synclines. There is also a closer agreement between surface structure and that of the oil-bearing limestone beneath the incompetent Lower Fars.

MASJID-I-SULAIMAN

The position of the oil-bearing structure is marked on the surface by copious seepages in the Lower Fars. The incompetence of this formation has resulted in an exceedingly complex surface structure which effectually conceals the existence of the broad simple anticline of Asmari limestone below; nor does the nature of this limestone at Asmari Mountain, 15 miles away, suggest the possibility of its being a prolific reservoir rock. It was thought at first that the production was obtained from limestones in the Lower Fars. The identity of the reservoir rock as the Asmari limestone was first established by S. J. Shand and his discovery was developed more fully by R. K. Richardson and other workers.

The Asmari limestone is 1,000 feet thick (Fig. 1). It consists for the most part of thick-bedded gray fine-grained foraminiferal rock (Fig. 2). In the lower half, the limestones are interbedded with thin shales and anhydrite bands. The limestone is underlain by marls and marly limestones, among which is a single anhydrite bed 22 feet thick, 120 feet below the base of the limestone.

The early wells on the Masjid-i-Sulaiman field were all drilled with cable tools; casing was set in the cap rock, the basal anhydrite bed of the Lower Fars, and the wells were continued until oil was struck. It so happened that in the small area first developed, locally named Maidun-i-Naftun (the plain of oil), conditions were not altogether typical of the field as a whole. Most of the early wells obtained production on penetrating only a few feet into the limestone, and the rock was said to be "honeycombed." Some wells blew out large quantities of rock, but unfortunately no samples have been preserved and no exact description of the nature has been recorded.

In 1924 R. K. Richardson[1] published a paper in which he ascribed the productivity of the reservoir rock to porosity caused by dolomitization, and in the discussion of that paper Professor H. de Böckh referred to the probable development of "rauchwacke" dolomites in zones where the limestone has a lagunal development, that is, where it is interbedded with anhydrite. Since that time, however, our knowledge of the reservoir conditions has been greatly extended and, al-

[1] R. K. Richardson, "The Geology and Oil Measures of South-West Persia," *Jour. Inst. Petrol. Tech.*, Vol. 10 (1924), pp. 1–30.

FIG. 1.—Gorge on southwest flank of Asmari Mountain exposing Lower Miocene limestone named after mountain.

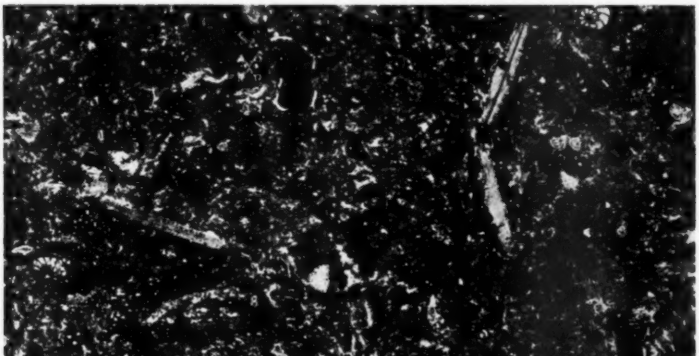

FIG. 2.—Microphotograph showing organic structure typical of Asmari limestone, Masjid-i-Sulaiman. Depth, 569 feet below top of limestone.

though it is still far from complete, we can definitely state that neither of these theories has been supported by subsequent investigations.

The Masjid-i-Sulaiman field has a length of 17 miles and an average breadth of 3 miles. Several wells have been drilled through the whole thickness of the limestone and about one-third of the total wells drilled have penetrated more than 100 feet true thickness of limestone. The depths into the limestone at which oil is struck bear no relation to definite horizons or to zones of characteristic physical type. A few wells have penetrated "tight" patches in the structure and have given little or no production; fortunately such patches are rare and local. A number of such wells have been shot in an attempt to improve production, but without result. The southwest flank is uniformly productive, although there is considerable variation in the capacity of the wells. The northeast flank has not been so extensively drilled, but the results have shown less uniform conditions. Non-productive areas have been found on both pitching ends of the structure, where several completely dry wells have been drilled.

During recent years, complete cores of the whole thickness of limestone have become available for study, and investigations into the petrological, physical, and chemical nature of the reservoir rock have been carried out. The data and descriptions here given are based largely on the work of J. McAdam, M. H. Lowson, and G. H. Hubbard, and also on the writer's personal observations.

Figure 3 shows the detailed logs of three wells drilled through the limestone, and Figure 4 shows how a distinctive zone with *Miogypsina* may be correlated from end to end of the structure.

The limestone at Asmari Mountain corresponds in general character and in thickness with the reservoir rock at the field, and within the field the succession remains remarkably constant. Slight differences in detail have indeed been recorded and there seems to be a tendency to thicken slightly towards the northwest.

In accounting for porosity conditions in limestone fields elsewhere, it has been suggested[1] that a one-time exposure of the crest of the limestone allowed circulation of ground water within it, with the consequent formation of solution cavities and channels. This is not the case at Masjid-i-Sulaiman. The constant thickness of the limestone shows that no appreciable amount of limestone is lacking anywhere on the structure. Also the upper surface does not show any erosional effects; instead, the cores show a transition from normal limestone into

[1] W. V. Howard, "Classification of Limestone Reservoirs," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 12 (December, 1928), pp. 1153–61; especially p. 1156, citing A N. Murray.

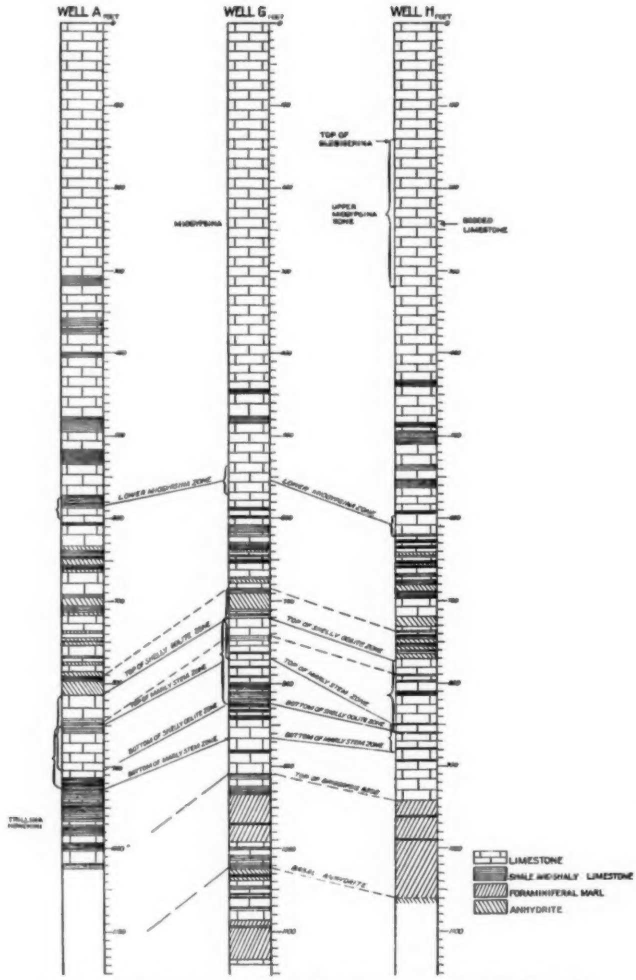

FIG. 3.—Detailed logs of Asmari limestone in three wells Masjid-i-Sulaiman. (For position of wells see Figure 4.)

the cap-rock anhydrite. It is true that the transition zone is confined to a few feet, indicating a fairly rapid change of conditions, but there is no clean-cut break. Figure 5 is a photograph of cap rock 3 feet above the top of the limestone. It shows wisps and stringers of foraminiferal limestone intermixed with anhydrite.

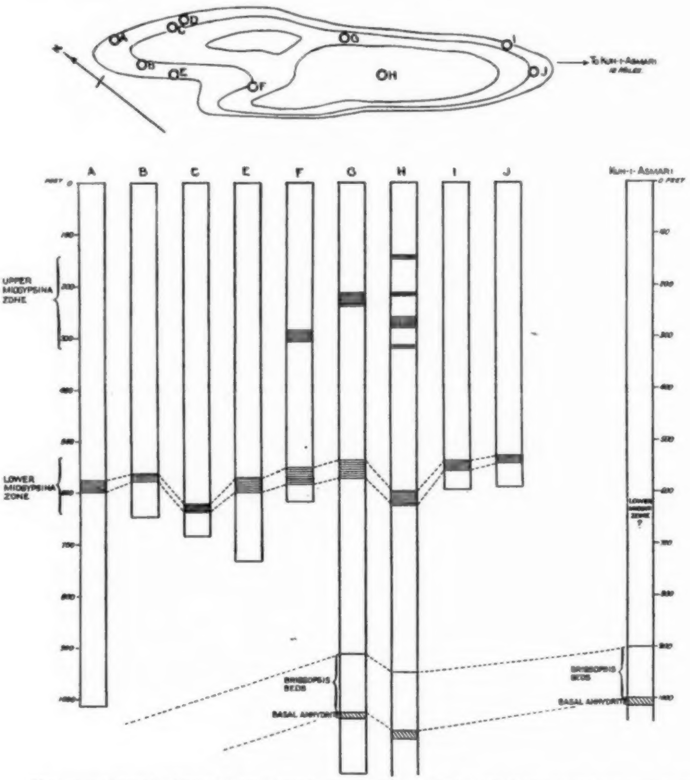

FIG. 4.—Correlation of limestone throughout Masjid-i-Sulaiman and comparison with Asmari Mountain (Kuh-i-Asmari). Wells mentioned in text are shown in plan.

The outstanding impression given by an inspection of the limestone cores is the normal fine-grained character of the rock and the lack of obvious porosity. A core brought up fresh from the oil zone may bleed gassy oil freely, but mainly or even entirely from cracks in the rock or from small mineralized veins (Fig. 6). Many of the cracks show slickensided faces indicating movement, but in most cases where

such a crack crosses a recognizable band in the limestone it can be seen that the amount of displacement is negligible. Faulting has been proved on the southeast-pitching end of the limestone fold, but the degree to which correlation of the limestone is possible throughout the field shows that faulting on any scale is not common. The cracks

FIG. 5.—Transition from Asmari limestone to Lower Fars. Masjid-i-Sulaiman.

FIG. 6.—Core of Asmari limestone when withdrawn. Oil is seeping from small cracks and cavities in rock. Masjid-i-Sulaiman.

exhibited in the cores, therefore, indicate a general shattering of the limestone without much relative movement within the rock. Most of the cracks observed in the cores are highly inclined, at angles of 70° and over, but of course any low-angle cracks would cause the core to break in the barrel and direct evidence of such fractures can not be expected.

Mineralized veins and cavities are not uncommon and their study

allows certain deductions to be drawn regarding the past history of the limestone. Such veins are mostly of calcite, though occasional veins of anhydrite and celestite have been found. Some cracks are completely filled, while others have an open vug lined with well formed crystals. The width of such veins averages about $\frac{1}{4}$ inch. These mineralized veins were formed before the oil concentration took place, for they are themselves an indication of circulating water free of oil. The fractures which acted as channels for oil movement are of later date and they frequently cut through the earlier mineralized veins. Where these veins are completely filled with mineral matter they are free of oil, but where a vein has an open vug it can, of course, carry oil. The mineralized veins are common to unproductive patches and productive areas alike and for this reason it seems improbable that they have any essential connection with the capacity of the limestone to carry oil. There may, however, be areas in which open veins and solution cavities have a greater development than anything found up to date, but even if this is the case it would have only local significance.

Most of the wells which have been drilled far into the limestone were continued because the upper part was tight or gave insufficient production. Until recently we have had no information regarding the vertical distribution of production in the limestone in areas of high production. A well deepened to explore this condition, using a formation tester, has shown that where the upper part of the limestone is prolific, production continues throughout its entire thickness. The core recovery of this well was exceptionally poor, indicating a highly shattered condition of the rock.

The conclusions drawn from inspection of the cores, and from the behavior of the wells, are, therefore, that the important factor governing the capacity of the Asmari-limestone as a reservoir rock is its shattered condition. The normal rock appears to be similar in prolific and non-productive areas alike, and the productive capacity is believed to depend on the degree to which fracturing has been effective. The performance of wells and pressure data show that there is very free connection, both laterally and vertically, throughout the reservoir.

A detailed investigation into the porosity and the degree of dolomitization has been carried out, and it has been shown that earlier conclusions published by R. K. Richardson[1] were based on insufficient evidence. Porosity determinations have been carried out by cutting pencils of the rock, extracting the oil content by benzol in a Soxhlet apparatus, drying, and then calculating the porosity by measuring the volume of carbon tetrachloride absorbed by the rock.

[1] *Op. cit.*

The results of this work are of importance in showing that the general porosity is low, that there is no simple relation between porosity and dolomitization, and that the primary nature of the solid rock is constant in productive areas and non-productive areas alike.

The bulk of the oil has been drawn from the upper 300 feet of the limestone and the following porosity determinations for this thickness in two wells may be cited as an example.

	Well D *Per Cent*	*Well H* *Per Cent*
Average porosity for over 140 observations	5.6	6.6
Proportion of observations over 10 per cent porosity	10	15
Highest porosity determined	22.84	19.25

Well *D* (see plan in Figure 4) is situated in an unproductive area and the cores show a complete lack of shattering and lack of free oil. Well *H* is situated in a good producing zone, although its own capacity is not known, and almost every 5 feet of core showed one or more fractures which were bleeding oil actively when withdrawn. These results show that the normal porosities are of the same order in both cases.

An investigation into a possible essential connection between porosity and dolomitization gave negative results. The following table gives the results in the upper 300 feet of limestone in well *H*.

Percentage of 56 Observations	*Percentage Dolomitization*	*Percentage Porosity*
13	Over 75	4.21–16.09
4	51–75	12.99–15.83
14	26–50	2.45– 8.93
21	11–25	1.47–12.00
48	Up to 10	1.07–13.01

Similar results were obtained from a large number of determinations from other wells and throughout the thickness of the limestone. The rock can not in any part be called a pure dolomite, nor has it the crystalline or sugary appearance typical of a dolomite. It is essentially a calcium carbonate rock with admixture of magnesium carbonate in varying proportions.

Permeability determinations have also been carried out and the results show that even the most porous rock yet found is quite incapable of accounting for the large capacity of many of the wells. There is no doubt that large wells are fed directly by fissures in the limestone, and probably much of the total oil in the reservoir is held in fissures. In spite, however, of the general low porosity of the rock, there is sufficient rock of medium porosity, between 10 and 15 per cent, to contain a very large quantity of oil. It is supposed that the oil entered

the reservoir rock via fissures and that the more porous parts have been filled from these channels. The fissures which supply producing wells are probably replenished from large faces of porous rock exposed to them. In the non-productive areas the lack of fissuring has prevented such porous rock as exists from becoming fully charged with oil, the body of the rock being apparently too dense to allow migration through its mass. Even in these areas, some parts of the limestone contain a little oil, but it is not recoverable.

The very free fluid connection which has been found by experience to exist throughout the reservoir is further evidence in support of the view that communication is via fissures and not via porous rock.

HAFT KEL

The reservoir rock of Haft Kel field is also the Asmari limestone. Systematic investigations into the porosity and permeability of the rock have not yet been carried out, but experience has shown that the same general conditions prevail as at Masjid-i-Sulaiman. The limestone is of the same nature, but with a greater development of anhydrite nodules in its upper part. As at Masjid-i-Sulaiman, some wells strike oil in quantity immediately below the cap rock, whereas others have been drilled as much as 200 feet into the limestone before obtaining sufficient production. There is considerable variation in the productive capacities of various wells, depending presumably on the degree of shattering in the limestone.

NAFT KHANEH

The stratigraphy of the Naft Khaneh field is shown in Figure 7. At Masjid-i-Sulaiman there is a sharp passage from Lower Fars shale, salt, and anhydrite to Asmari limestone, and no oil showings of any consequence are encountered in the Lower Fars. At Naft Khaneh, however, the basal part of the Lower Fars is a transition zone containing a number of limestones or groups of thin limestones interbedded with anhydrite and shale. The entire production of Naft Khaneh up to date has been drawn from these limestones. The Kalhur limestone is 235 feet in thickness and is also oil-bearing. It is in part a foraminiferal limestone, in part somewhat dolomitic with only obscure traces of organic structure, and in part oölitic. The limestone is underlain by about 400 feet of anhydrite, salt, and thin limestones, below which lie marls and marly limestones similar to those underlying the Asmari limestone at Masjid-i-Sulaiman. The anhydrite and salt indicate a locally intense lagunal phase, represented at Masjid-i-Sulaiman by thin beds of anhydrite in the lower part of the Asmari limestone.

The Naft Khaneh field lies across the Iraqi-Persian frontier, but as far as the reservoir rock is concerned it can not be said to be typical of the fields of either country. A description of the reservoir rocks of the Iraq fields is outside the scope of this paper, but it must be mentioned

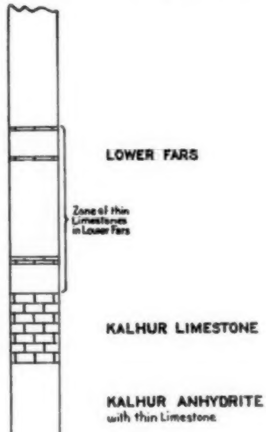

FIG. 7.—Stratigraphy in Naft Khaneh field.

that although the oil-field belt is continuous from Persia into Iraq. there are many differences both structurally and stratigraphically. In much of Iraq the Lower Miocene limestone is very poorly developed or is absent altogether, and the reservoir rock is of Oligocene and Eocene age with, in general, a more porous character.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 17, NO. 3 (MARCH, 1933), PP. 241-253, 3 FIGS.

PERMIAN OF LOGAN AND LINCOLN COUNTIES, OKLAHOMA[1]

JOSEPH M. PATTERSON[2]
Lawrence, Kansas

ABSTRACT

The lower Permian beds of Logan and Lincoln counties, Oklahoma, are described and their thicknesses measured. Some new subdivisions have been introduced, new names submitted, and a map showing their areal distribution made.

The alternating red sandstone and red shale beds from the base of the Permian up to and including the Garber sandstone are thought to have been deposited, for the most part, under deltaic conditions.

INTRODUCTION

In the course of more than two years of detailed structural mapping in Logan and northwestern Lincoln counties, Oklahoma, the writer has been able to partially re-subdivide the formations of the lower Enid group of the Permian. The writer realizes the incompleteness of the work, but since his investigations have been terminated in the area, it may be of benefit to make known the results thus far obtained.

Nothing has been published to materially show, in more detail, the approximate areal extent of the formations of the lower Enid of this area since Aurin, Officer, and Gould's[3] paper was published in 1926.

ACKNOWLEDGMENTS

The writer wishes to thank A. A. Langworthy and Ira H. Cram for their coöperation and encouragement in the preparation of this paper.

The problems have been discussed with various field geologists working in the area. Mechanical analyses of sandstone samples from this area and a laboratory study of the dolomitic conglomerates were made under the direction of G. L. Knight, of the department of geology, University of Kansas, Lawrence, Kansas.

[1] Manuscript received, August 6, 1932. Published by permission of The Pure Oil Company.

[2] Box 359.

[3] F. L. Aurin, H. G. Officer, Charles N. Gould, "The Subdivisions of the Enid Formation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 8 (August, 1926) pp. 786–99.

PHYSICAL CONDITIONS

Elevations in Logan and northwestern Lincoln counties range from 850 to 1,200 feet above sea-level. The main drainage is to Cimarron River, which flows eastward through the northern part of the area. Due to fairly mature topography throughout a considerable part of the area, outcrops are abundant enough for detailed work. Vegetation is an aid in correlating sandstones and shales in this area. Blackjack oak trees grow well in sandy soil, but generally do not grow in clayey or shaly soil.

STRATIGRAPHY

GENERAL

In starting work in the area the field geologist is confronted with the fact that none of the subdivisions or horizons on the north is easily recognizable in the area except the Cushing limestone near the base of the Permian, and the top of the Garber formation 1,800 feet above the Cushing limestone. Alternating red sandstone and red shale beds which are monotonously similar in appearance comprise the 1,800 feet of intervening beds. Few of the beds above the Cushing limestone are resistant enough to make prominent escarpments. Therefore, structural determination is extremely tedious, and because of variations in the thicknesses of the beds, correlations are hazardous. Changing currents during deposition have caused beds to thicken and thin, to be channeled, and to be terminated so abruptly as to resemble faulting. Bases of sandstones where they are in contact with shales are ordinarily somewhat wavy and where exposed in railroad cuts consist of a series of scallops which are as much as 20 feet across and several feet in height. These irregularities in the bases of the sandstones may have resulted from the scooping out of the tops of the underlying shales by strong currents associated with the incoming sand deposition.

The shales are jointed and break with a conchoidal fracture. Bedding planes are rarely found. All the shales contain considerable silt.

A vertical section from the base of the Foraker limestone to the top of the Garber sandstone is shown in Figure 1. All but the lower few hundred feet were studied, but an accurate interval from the top of the Cushing limestone to the base of the Fallis[1] sandstone was obtained from core-drill information supplied by Charles C. King.[2]

The areal distribution of the formations is shown in Figure 2. New names have been introduced. Whether or not they deserve the rank

[1] Name available according to the records of the Committee on Geologic Names, United States Geological Survey.

[2] Charles C. King, 804 Wright Building, Tulsa, Oklahoma.

assigned them will depend on the results of future detailed work in this area and the adjacent territory.

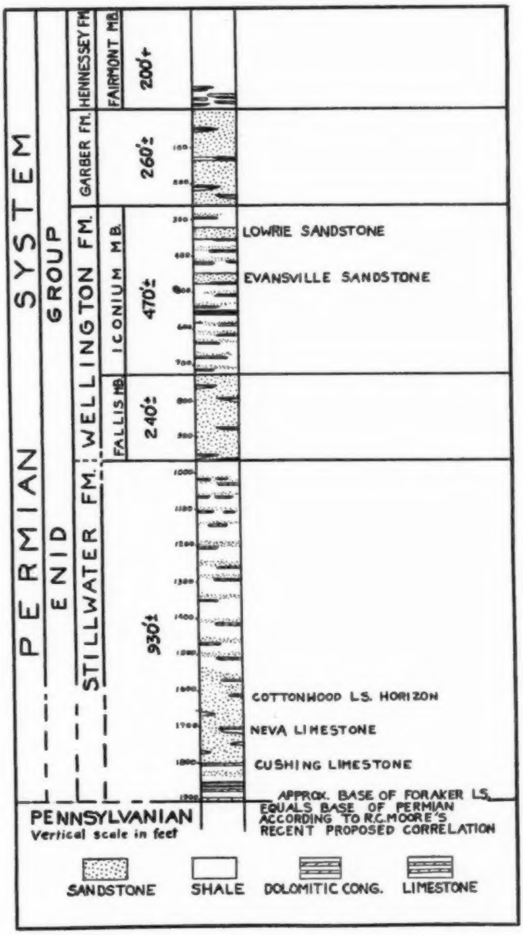

FIG. 1.—Generalized Permian section in T. 16 N., Rs. 5 E.-4 W., Logan and Lincoln counties, Oklahoma.

This is the region where red-bed deposition started down in the Pennsylvanian. The color change from grays and blues to reds is not

the dividing line for separating the Pennsylvanian from the Permian.[1] The writer uses the base of the Foraker limestone for the base of the Permian, since the base of the Foraker limestone is the horizon at which R. C. Moore puts the Pennsylvanian-Permian contact in recent correlations.[2]

The writer is not qualified to discuss the merits of the various horizons that have been used in the past for the base of the Permian. Moore's correlation is taken because it is the most recent and is more serviceable for this area than some of the others.

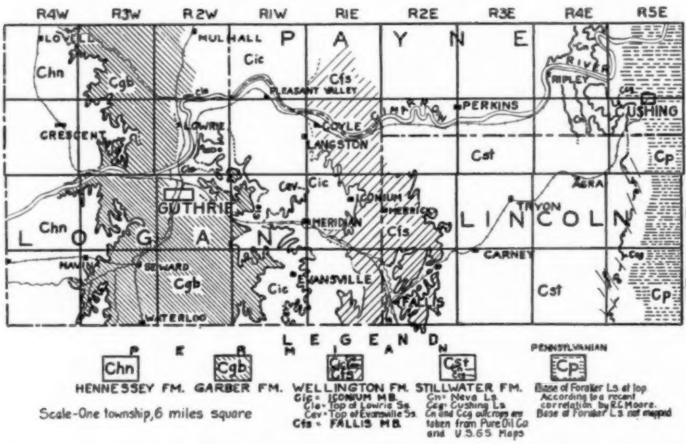

FIG. 2.—Map showing areal geology in portions of Logan, Lincoln, and Payne counties, Oklahoma.

The regional dip is slightly south of west at the rate of about 35 feet per mile.

DOLOMITIC CONGLOMERATES

Throughout, the formations described in this paper are dolomitic conglomerates occurring as beds which are usually thin compared with the shale and sandstone beds, few of them being more than 5 feet in thickness. The conglomerates generally are present at the bases of

[1] Charles N. Gould, "The Correlation of the Permian of Kansas, Oklahoma and Northern Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 2 (February, 1926) pp. 144–53.

[2] R. C. Moore, "Correlation Chart of Post-Devonian Rocks in Part of the Midcontinent Region," *Guide Book, Fifth Annual Field Conference*, sponsored by the Kansas Geological Society (August 30 to September 5, 1931).

Raymond C. Moore, "A Proposed New Type Section of the Pennsylvanian System." Paper presented at the Forty-Fourth Annual Meeting, *Geol. Soc. Amer.* (Tulsa, Oklahoma, December 29–31, 1931).

sandstones. Here and there they are developed as separate beds in the shales and in a few cases they are found as lenses of small area inclosed in massive cross-bedded sandstones. In any occurrence the conglomerates are discontinuous.

Dott[1] calls the beds "pseudo-conglomerates" in describing the formations of the Enid group exposed in Garvin County, Oklahoma.

A study of these dolomitic conglomeratic beds has been made by Merritt and Minton.[2] The beds are tentatively considered by them to be intraformational conglomerates.

Wegemann[3] very thoroughly describes similar beds in the Wichita formation of southern Oklahoma. These conglomerates evidently have a widespread distribution throughout the lower Permian beds of Oklahoma.

The writer's observations on the pebbles of these conglomerates suggest that they consist mostly of sandy shaly dolomite, red to gray in color. Fragments of shale are present in minor amounts. Some of the sandy dolomitic pebbles are laminated; however, laminated pebbles are rare. Many of the nodules are veined with calcite or dolomite. Practically all of the pebbles, laminated, non-laminated, or septarian in character, contain detrital quartz, in varying amounts, which is generally of much finer texture than that found in the matrix. All shapes from angular to spherical are developed with rounded forms predominating. Many of the rounded septarian nodules are very similar to concretions found in the red shales of this area. The pebbles vary in size from microscopic dimensions to as much as 3 inches in diameter. In a single specimen the pebbles vary from one another in size, shape, color, dolomite content, shale content, sand content, size of contained quartz grains, laminations, veining, et cetera.

The matrix in most specimens is predominantly sand, but it varies from almost pure sand to almost pure dolomite. In thin sections, the sand grains of the matrix are usually conspicuously larger than the detrital quartz grains of the pebbles; however, the sand grains in the matrix are not noticeably different in size and character from the sand grains making up the associated sandstone beds. In some cases the matrix composes most of a specimen with only a few scattered peb-

[1] Robert H. Dott, "Garvin County," *Oklahoma Geol. Survey Bull. 40*, Vol. 2 (July, 1930), p. 127.

[2] C. A. Merritt and J. W. Minton, "The Dolomites of the Stillwater, Wellington, Garber, Hennessey and Duncan Formations," *Oklahoma Acad. Sci.*, Vol. 10 (November, 1930), pp. 69–72.

[3] Carroll H. Wegemann, "Anticlinal Structure in Parts of Cotton and Jefferson Counties, Oklahoma," *U. S. Geol. Survey Bull. 602* (1915), pp. 17–20.

bles, whereas in other cases the pebbles are so closely packed that the matrix is only a small percentage of the whole.

The present opinion of the writer is that the beds are intraformational conglomerates as suggested by Wegemann, and by Merritt and Minton. The dolomite fragments are from dolomitic deposits that may have formed in the drying up of playa lakes on an old delta, in times of drouth. Later the dolomite and shale beds, possibly sun-cracked, were broken and redeposited by strong currents. Concretions similar

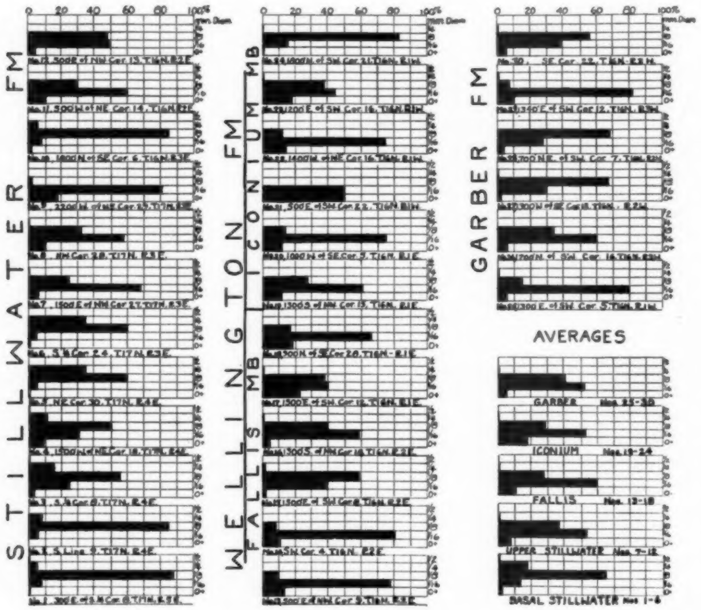

FIG. 3.—Histograms of textural analyses, made from representative samples of Stillwater, Wellington, and Garber formations, Ts. 16, 17 N., Rs. 4 E.-3 W., Logan and Lincoln counties, Oklahoma.

to the ones found in the red shales of this area were washed in also, to be mingled with the fragmental dolomite and shale types of pebbles. The main bulk of the pebbles, in any case, is thought to be older than the matrix. The differences in the ages of the pebbles and the beds in which they have been deposited are probably not sufficient to allow the conglomerates to be classified other than as intraformational.

STILLWATER FORMATION

The writer has not studied the Stillwater in detail but a few observations are worthy of note. Aurin, Officer, and Gould proposed that the Stillwater should represent the beds from the base of the Permian up to the top of the Herington limestone. Therefore the base of the Stillwater is at the base of the Foraker limestone, if Moore's correlation for the base of the Permian is used.

The top of the Cushing limestone is nearly 100 feet above the base of the Foraker limestone north of this area in T. 22 N., Rs. 2 W.-5 E., according to Clark and Cooper.[1] The total thickness from the Cushing limestone to the base of the Fallis sandstone is about 830 feet as determined from core-drill information. Therefore an approximate thickness for the Stillwater formation, the base of the Foraker limestone being considered as its base and the base of the Fallis sandstone as its top, is 930 feet for northern Lincoln County.

The approximate 100 feet of beds between the base of the Foraker limestone and the top of the Cushing limestone are blue and red shales, thin limestones, and some red sandstones.

The beds for several hundred feet above the Cushing limestone are mostly red sandstones predominating over red shales. The sandstones are friable, micaceous, and coarser than any of the overlying sandstones discussed in this paper. Some of the quartz grains are above 0.5 mm. in diameter, which is a size grade above that found in the sandstones of the Wellington and Garber formations. Muscovite flakes as large as 5 millimeters in length are common. The shales are red and resemble the rest of the shales of the lower Enid. Discontinuous beds of impure dolomite and dolomitic conglomerates are found throughout.

Higher in the column the Stillwater becomes shaly. The gradation seems to be slow and not a rapid change from predominant sandstone to predominant shale. At the top of the formation a distinct break is present between the upper shaly Stillwater and the base of the thick, massive, soft Fallis sandstone.

The beds of the upper half of the Stillwater are shales, sandstones, and dolomitic conglomerates. The shales are red in color, non-laminated, and contain septarian dolomitic concretions and veined geodes. The sandstones are friable, red, and micaceous. Ninety-five per cent of the grains of angular to subangular quartz forming the sandstone beds were found to be less than 0.25 millimeter in diameter in a me-

[1] G. C. Clark and C. L. Cooper, "Kay, Grant, Garfield and Noble Counties," *Oklahoma Geol. Survey Bull. 40*, Vol. 2 (April, 1930), p. 68.

chanical analysis of six representative samples from T. 16 N., Rs. 2 and 3 E., Lincoln County. In every way these sandstones are similar to the sandstones of the Wellington and Garber formations. Dolomitic conglomerates are usually present at the bases of the sandstones.

The Herington limestone and its southern equivalent have been defined as the top of the Stillwater by Aurin, Officer, and Gould.[1] Since neither the Herington limestone nor its southern equivalent has been recognized in the area, it is suggested that the top of the Stillwater be placed at the base of the Fallis sandstone, for reasons given in the following paragraphs.

The type locality of the Stillwater-Fallis contact is at the north edge of the town of Fallis, 500 feet S. and 150 feet E. of the NW. cor. of Sec. 29, T. 15 N., R. 2 E., Lincoln County. The approximate elevation is 915 feet. About 15 feet of Stillwater sandy red shale is exposed below the contact; more than 40 feet of Fallis, massive sandstone, above the contact.

WELLINGTON FORMATION

The name Wellington is here used to include the Fallis sandstone as a lower member and the Iconium[2] shale as an upper member. The thickness and areal extent of the combined Fallis and Iconium beds correspond roughly to those attributed to the Wellington by Aurin, Officer, and Gould.[3]

The base of the Fallis is apparently not far from the Herington horizon, which has been defined as the base of the Wellington. According to Clark and Cooper[4] the Herington can be traced south from Kansas as far as T. 22 N., R. 2 E., Noble County, where it dies out. This is 30 miles north of the area under discussion. Due to discontinuous exposures and lateral changes in the beds between the two areas, it is doubtful if the base of the Fallis sandstone can be exactly correlated with reference to the horizon of the Herington limestone.

For Logan and Lincoln counties, Oklahoma, it is proposed that the base of the Wellington be placed at the base of the Fallis sandstone. The base of the Fallis is suggested because of its stratigraphic position, the pronounced lithologic change present there, and for convenience in mapping.

Fallis member.—For the thick sandstone composing the basal 240 feet of the Wellington formation, as redefined in preceding para-

[1] *Op. cit.*, p. 792.

[2] Name available according to the records of the Committee on Geologic Names, U. S. Geol. Survey.

[3] *Op. cit.*, p. 794.

[4] *Op. cit.*, p. 73.

graphs, the name Fallis is proposed. The name is taken from the town of Fallis, Sec. 29, T. 15 N., R. 2 E., Lincoln County. The post-office of Fallis is about 40 feet above the base of this sandstone.

In this area the Fallis is at least 90 per cent sandstone. The sand grains composing the sandstones are rather small. In the screen analyses of six representative samples from T. 16 N., Rs. 1–2 E., the grains are less than 0.25 millimeter in diameter. The sandstones are friable, micaceous, and reddish brown. Fossil wood and imperfect barite rosettes are found locally. The base of the Fallis is marked in places by a dolomitic conglomerate bed about two feet in thickness which forms ledges in T. 15 N., R. 2 E. Red shale lenses with a maximum thickness of 20 feet occur in the Fallis sandstone. The tops of the shales are generally marked by dolomitic conglomerates. Shale lenses in several localities terminate so suddenly as to resemble faulting, but the causes are really depositional. A notable example of this is to be found in the abandoned railroad cut 500 feet S. and 500 feet E. of the NW. cor. of Sec. 2, T. 15 N., R. 2 E.

Reconnaissance on the north side of Cimarron River has shown the Fallis to contain increasingly more shale interstratified with the sandstones as it is followed northward. West of Stillwater the Fallis is probably 50 per cent shale, which corresponds to the northward change from sandstone to shale that takes place in the Garber formation.

The type locality for the Fallis-Iconium contact is $1\frac{1}{2}$ miles east of the town of Iconium, 50 feet E. of the SW. cor. of Sec. 12, T. 16 N., R. 1 E., Logan County. The approximate elevation is 1,109 feet. More than 70 feet of massive sandstone is well exposed below the contact; red shales and thin sandstones are above the contact.

Iconium member.—The name Iconium is proposed for the upper shaly part of the Wellington occurring between the top of the Fallis sandstone and the base of the Garber sandstone. The Iconium derives its name from the little town of Iconium located near the south quarter corner of Sec. 10, T. 16 N., R. 1 E., Logan County. Stratigraphically the town is about 80 feet above the base of this member of the Wellington.

The thickness of the Iconium is about 470 feet through T. 16 N., Rs. 1 E.-1 W. The lower 270 feet is about 65 per cent shale. The sandstone and dolomitic beds are well spaced and are very satisfactory for detailed work.

The upper 200 feet of the Iconium contains more sandstone beds with the shale beds. The change from Wellington to Garber is gradational, but the top of the Iconium has been placed at the base of the massive sandstone of the Garber. The Garber from Cimarron River

south is characterized by an almost continuous vertical section of massive sandstone as contrasted with the interbedded sandstone and shale beds of the upper Iconium.

The shales of the Iconium are red, blocky, non-laminated, and contain calcareous or dolomitic material in the form of septarian concretions and veined geodes.

The sandstones are friable, reddish brown to gray, micaceous, and cross-bedded. They are relatively fine in texture. In mechanical analyses of six representative samples from T. 16 N., Rs. 1 E.-1 W., the sand grains were found to be less than 0.25 millimeter in diameter. More than 95 per cent of the grains are angular to subangular quartz. Shifting currents and channeling at the time of deposition cause beds to be discontinuous, but the thicker sandstones, even though sharply terminated and abutted by shales, are found to reappear in their respective stratigraphic horizons. Fossil wood is found in recently exposed sandstone surfaces. An abundance of fossil wood is present one mile east of Iconium, where the abandoned Rock Island right of way crosses the east-west section line.

There are a few thin calcareous or dolomitic beds, usually red in color, in the lower Iconium, that are chemical precipitates lacking the conglomeratic appearance which is so common in the dolomites of the lower Enid. Yet, by far, most of the dolomites that occur in the Iconium are conglomeratic, and, as usual, they are best developed at the bases of the sandstones.

Localities that have been correlated as the top of the Iconium are as follows.

One locality is 300 feet S. of the NW. cor. of Sec. 29, T. 16 N., R. 1 W., Logan County. The approximate elevation is 1,134 feet. The exposure shows the top of the shale and the base of the sandstone.

Another locality is 1,850 feet S. of the NW. cor. of Sec. 28, T. 15 N., R. 1 W., Logan County. The approximate elevation is 1,157 feet. The exposure shows the top of the shale and the base of the dolomitic conglomerate and sandstone.

In the upper half of the Iconium two important sandstone beds are present in Logan County. The lower of the two, the top of which is about 180 feet below the top of the Iconium, has been named the Evansville[1] sandstone. The upper one, the top of which is about 60 feet below the top of the Iconium, has been named the Lowrie[2] sandstone.

[1] Name available according to the records of the Committee on Geologic Names, U. S. Geol. Survey.

[2] Name available according to the records of the Committee on Geologic Names, U. S. Geol. Survey.

Evansville sandstone bed.—The name Evansville is proposed for a sandstone bed that heretofore has been called by some geologists the Bu-Vi-Bar bed because it is well developed near a dry hole drilled by the Bu-Vi-Bar Oil Company close to the town of Evansville. The bed has been traced from the south line of Logan County to the north line of T. 16 N., R. 1 W. This sandstone is massive, cross-bedded, friable, and reddish brown in color. It averages about 25 feet in thickness. The top of the bed is exposed ¾ mile east of Evansville with an approximate elevation of 1,120 feet, but the bed is better observed as conspicuous ledges south of there, for instance, at a locality 500 feet N. of the SW. cor. of Sec. 25, T. 15 N., R. 1 W., Logan County. The approximate elevation is 1,062 feet. The exposure shows the top of the bench-making sandstone and the base of the shale.

Lowrie sandstone bed.—A few miles north of Guthrie, vertical bluffs are present on the east side of Cimarron River. These bluffs are in the central part of T. 17 N., R. 2 W., and it is here proposed that the 45-foot massive sandstone bed associated with the red shales of these bluffs, be named the Lowrie sandstone bed, from the railroad station of Lowrie in Section 16. From place to place the Lowrie bed varies from 20 to 45 feet in thickness. In texture, color, and composition it is like the rest of the sandstone beds of the Iconium member of the Wellington.

A locality in the bluffs east of Lowrie where the bed can be observed in detail is 1,500 feet W. of the center of Sec. 22, T. 17 N., R. 2 W., Logan County. The approximate elevation is 975 feet. The top of the 45-foot massive Lowrie sandstone, and the base of the red shales are shown.

GARBER FORMATION

The Garber gets its name, according to Aurin, Officer, and Gould,[1] from the town of Garber in Garfield County, Oklahoma. In the same discussion it is divided into a basal shale member called Lucien and an upper sandstone member called Hayward.

The base of the Lucien, which is the base of the Garber, has not been traced by the writer south from its type locality at Lucien in western Noble County; however, Cornelius Schnurr[2] has traced the base of the Lucien from a point 5 miles west of Perry, Oklahoma, south, to the bluffs along the north side of Cimarron River, two miles north of Lowrie.

[1] *Op. cit.*, p. 794.

[2] Cornelius Schnurr, personal communication dated June 6, 1932.

Concerning the Wellington-Garber contact, Schnurr says:

—it occurs well up toward the tops of the bluffs on the north bank of the Cimarron river, about 60 feet above the level of highway 77 that follows the north bank of the river at this point. The bluffs on the east side of the river a few miles northeast of Guthrie I believe to be upper Wellington with the possibility that the contact is somewhere near the tops of those bluffs.

From his description Schnurr locates the contact not more than 20 feet below where the writer has placed it on the basis of stratigraphic position and lithology.

The thickness of the Garber, including the Hayward and the Lucien, is about 260 feet in central Logan County. It probably thins slightly northward and thickens southward to approximately 300 feet at the south line of the county. There is no basis for separating the Lucien from the Hayward in Logan County.

Aurin, Officer, and Gould specify 600 feet as the thickness of the Garber. They indicate considerable more thickness and a greater breadth of outcrop for the Garber formation of this area than the writer has found. It may be said that, since their figures for contacts and thicknesses are only approximations, the thicknesses and areal distribution which they assign to the formations are not expected to be exact. The base of the Garber as shown by them is not far from where the writer has mapped it, but the top of the Garber in northern Logan County is shown about 6 miles west of where the writer shows the contact.

Noel Evans[1] has traced the generally recognized top of the Garber at Oklahoma City, northward, to the north edge of the town of Hayward in eastern Garfield County. At Hayward, the top of the Garber is almost in the middle of the areal breadth of the Garber as shown by Aurin, Officer, and Gould.[2] They draw the Garber-Hennessey contact from a point 5 miles west of Garber, southward to Oklahoma City, and northward to Kansas. Surface work has shown that they can not be correct at Oklahoma City and at the points west of Guthrie and Hayward also. Since most geologists familiar with the area are agreed on the top of the Garber at Oklahoma City, and since no one can find a horizon for the top of the Garber as they show it west of Guthrie, Hayward, and Garber, it is proposed that the top of the Garber be taken as that recognized at Oklahoma City. This horizon is shown correctly by Travis[3] on his geologic map of Okla-

[1] Personal communication.

[2] *Op. cit.*, p. 788.

[3] A. Travis, "Oklahoma County," *Oklahoma Geol. Survey Bull. 40*, Vol. 2 (July, 1930), pp. 433–60. Map No. 37.

homa County. This is the approximate horizon mapped by Anderson[1] as the top of the Garber in Cleveland County. This is the Garber-Hennessey contact mapped by the writer in Logan County. It is the best break from predominant sand deposition to predominant shale deposition. It is a much more mappable contact than that originally indefinitely defined as the top of the Garber by Aurin, Officer, and Gould.

The Garber of southern Logan County is probably 90 per cent sandstone, whereas at the north line of the county it is about half sandstone and half shale beds. The upper 20–30 feet of the Garber is very persistent and continues north of Logan County as a massive sandstone bed as far as Hayward, at least.

The sandstones of the Garber are gray to reddish brown. The grains of angular-to-subangular quartz composing more than 95 per cent of the sand particles in the sandstone beds are less than 0.25 millimeter in diameter, from mechanical analyses of six representative samples taken through T. 16 N. Muscovite flakes are everywhere present in the sandstones, but they are not noticeable until a specimen has been pulverized and treated with acid. The sandstones are friable and cross-bedded. They contain concretionary iron and barite rosettes. Barite rosettes have not been found to occur in such definite horizons as to be valuable for correlation purposes. Worm trails and fossil wood are commonly found in the sandstones.

The shales of the Garber of Logan County are red, non-laminated, and sandy. Concretions of barite and dolomite are found in these shales.

Dolomitic conglomerates are generally intermittently exposed at the bases of the sandstones.

Points correlated as the top of the Garber formation are as follows.

One locality is 300 feet E. of the NW. cor. of Sec. 6, T. 18 N., R. 3 W., Logan County. The approximate elevation is 989 feet. The top of the massive sandstone and the base of the shale are shown.

Another locality is the SW. cor. of Sec. 19, T. 15 N., R. 3 W., Logan County. The approximate elevation is 1,000 feet. The top of the massive sandstone and the base of the Hennessey shale are shown.

HENNESSEY SHALE FORMATION

The Hennessey was named, and divided into a lower and an upper member by Aurin, Officer, and Gould. The lower member was

[1] G. E. Anderson, "Cleveland and McClain Counties," *Oklahoma Geol. Survey Bull. 40*, Vol. 2 (July, 1930), pp. 179–92. Map No. 21.

named Fairmont and the upper member named Bison Banded. Since the beds lying above the redefined top of the Garber are predominantly red shale for several hundreds of feet, it is proposed that the basal member of the Hennessey include the beds between the top of the redefined Garber and the base of the Bison Banded member of the Hennessey. Part of the Fairmont as thus redefined was mapped as Garber by Aurin, Officer, and Gould.

Fairmont member.—At least 200 feet of the lower part of the Fairmont shales are exposed above the Garber in Logan County. The Fairmont is at least 90 per cent shale and, therefore, is more of a shale formation than the Iconium. Thin beds and lenses of fine sandstone are found throughout, however.

The shales are not noticeably different from the shales of the lower formations of the Permian. They are red, blocky, non-laminated, sandy, and contain dolomitic concretions. Sun cracks are found locally in the Fairmont shales.

Lenses of sandstone resembling the Garber sandstone immediately below, are found associated with the red shales of the basal 50 feet of the Fairmont. In certain areas, sand lenses of this zone cause confusion in correlating the top of the Garber, especially where they are exceptionally developed. The sandstones above the basal 50 feet are very fine, being finer grained than any of the sandstones of the Stillwater, Wellington, or Garber formations. The sandstones are reddish brown to gray in color, thin, cross-bedded, and lenticular. The beds are rarely more than 5 feet thick. The sandstones can be followed and correlated for short distances only, because of their discontinuity and because of the blanket of recent soil and sand over much of the Fairmont outcrop.

Thin dolomitic conglomerates are found generally at the bases of the sandstones.

CONCLUSION

The formations from the Cushing limestone to the top of the Garber sandstone have their maximum thicknesses in central Oklahoma County, immediately south of Logan County. Also the sand content of these formations is greatest there. The formations thin and the beds become shaly toward the south, west, and north. These beds are about 2,000 feet thick in Oklahoma County and, according to Dott,[1] have less than half that thickness in McClain County, on the south. Toward the west the sandstones are replaced by shales, as in-

[1] Robert H. Dott, "Lower Permian Correlations in Cleveland, McClain, and Garvin Counties, Oklahoma." *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 2 (February, 1932), p. 133.

dicated by subsurface information. Toward the north these beds thin slightly, and interfinger and grade into beds of a marine facies, changing upward into a salt basin facies.

It seems that these Permian beds in Logan and western Lincoln counties have their source, for the most part, in sediments from a large stream entering the Permian basin from the east at about the latitude of central Oklahoma County.

DISCUSSION

JOHN C. ROSS, Tulsa, Oklahoma (written discussion received, August, 1932): This paper by Mr. Patterson is the latest of several recent publications devoted to the unraveling of the detailed successions of the numerous beds making up the "Lower Enid" of Gould.[1] The paper is a credit to the patience and skill of Mr. Patterson, and the thanks of his fellow workers are due to him and to the Pure Oil Company. Such papers provide an excellent datum for newcomers to the area treated.

It is easy to exaggerate the importance of definitions and of nomenclature, and criticisms in this sense may seem ungracious and trifling, but Mr. Patterson's area is not large, and the thickness of his section not great, and some comment may be warranted.

Local names, as Fallis, Iconium, Evansville, Lowrie, are of great convenience to men working in a common area. It may be doubted if in a small area, as a county, such names ought to be published until the extension of the bed be sufficiently great to warrant such recognition. It might be better to defer naming these units until they can be shown to extend over a larger area. However, Mr. Patterson has excellent precedent.[2]

More serious objection can be made to what amounts to a redefinition of the formations established by Aurin, Officer, and Gould, in 1926. This paper is the foundation on which later work must be based, or at least until their divisions are superseded. The paper was defective in that type areas of the new formations were not definitely set out, and no means were provided for identifying the contacts and working them both ways. The paper was published before the present mass of detail was accumulated, and was admittedly subject to revision. In the Logan County area their divisions are readily made out, at least in a thin zone, and it is not certain that they should be changed. Patterson's divisions are more prominent beds, and so far as the Logan County area is concerned, more convenient. Agreement, however, would have to be reached concerning a much greater area, from Garvin to Noble, to upset the boundaries established by the nomenclators.

JOSEPH M. PATTERSON (reply received, February 16, 1933).—In reply to the discussion by Mr. Ross, the writer wishes to emphasize the fact that he has adhered as closely as it is possible to the formational definitions of Aurin,

[1] Charles N. Gould, "Geology and Water Resources of Oklahoma," *U. S. Geol. Survey Water Supply Paper 148* (1905).

[2] "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma," *U. S. Geol. Survey Bull. 686*.
C. W. Tomlinson, "The Pennsylvanian System in the Ardmore Basin," *Oklahoma Geol. Survey Bull. 46* (1929).

Officer, and Gould. The writer was obliged to name the most evident lithologic subdivisions because they have not been described before. The formational names have been retained, although in time, as studies of detail are continued, it is thought that Stillwater and Wellington as formational names will have to give way to group rankings.

The boundary on which the writer takes issue with Aurin, Officer, and Gould, is on the top of the Garber from Oklahoma City, north. There seems to be an agreement with most geologists on Anderson's top of Garber in Cleveland County as well as Travis' top of Garber in Oklahoma County. The writer has carried their contact northward through Logan County, and from reconnaissance work he has satisfied himself that Evans is correct in placing this same top of Garber at Hayward, in Garfield County. This briefly traces the writer's contact of Garber-Hennessey, from Garvin County to Noble County.

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VOL. 17, NO. 3 (MARCH, 1933), PP. 257-267, 5 FIGS.

CORRELATION OF REFLECTION SEISMOGRAPH RECORDS IN CALIFORNIA[1]

HENRY SALVATORI[2]
Dallas, Texas

ABSTRACT

Reflection records in California can not always be correlated on the basis of character, interval, et cetera. In those areas where the reflecting strata are not persistent or are subject to lateral changes in physical character a knowledge of the slope of the strata is essential for the proper interpretation of the records. A brief outline of a method for determining the dip of a reflecting surface is presented and the manner in which this method may be utilized to aid in the correlation of records is indicated. The major areas of California offering possibilities for reflection work are classified according to their geologic sections into two general groups, and typical reflection records secured in an area of each group are reproduced and discussed.

INTRODUCTION

During the past 15 months the reflection seismograph has been successfully employed in California to delineate subsurface structure in many widely separated areas. With recent improvements in instruments and technique, many of the difficulties that were at first encountered in some regions have been overcome, and at present there are very few areas in California of interest from the standpoint of oil and gas accumulation and with appreciable sedimentary sections, where the reflection seismograph can not be applied with reasonable assurance of success.

With a few minor exceptions, wherever the charges are detonated in holes of proper depth and the reflecting beds are not too badly fractured or very nearly vertical, little difficulty is experienced in securing good reflections from several strata. However, the problem of correlating these reflections is quite complex and sometimes presents considerable difficulty.

The purpose of this paper is to describe a method for determining the dip of reflecting beds, and to outline briefly the general method of correlating reflection records in the major areas of California which are of interest to the petroleum geologist. In what follows it is assumed that the reader has some familiarity with the elementary

[1] Manuscript received, December, 1933.

[2] Geophysical Service, Incorporated.

theory and general method of operation of the reflection seismograph. For those who are entirely unfamiliar with the fundamental principles, a paper by Eugene McDermott, published in the November, 1931, issue of the *Bulletin* of the Association,[3] is highly recommended.

DETERMINATION OF DIP

It is obvious that if the geologic section of a given area contained only one very hard stratum, such as limestone, which was overlain by a comparatively soft formation, such as shale, the problem of correlating reflection records would be exceedingly simple. Reflection records obtained in such an area would show only one outstanding reflected wave, and consequently, there could be hardly any possibility of error in the correlation.

But since in general the geologic section contains many strata which act as good reflectors of wave energy, the problem of correlation is rendered somewhat complex. The complexity of the problem, of course, increases in proportion to the number of reflecting beds, their degree of uniformity in reflecting efficiency, and the amount of variation in the lithologic character of the beds from point to point. If there are a great number of reflecting horizons but only a few of these act as superior reflectors, the reflected energy from these horizons will appear on the records as outstanding, and little difficulty will be had in identifying them on records taken over various points. Where, however, the section contains a great number of equally good reflecting strata, some of which change in character, and therefore in reflecting efficiency, over the area under investigation, the correlation of the records oftentimes becomes too complex to be effected by means of a study of record character alone. In those cases the dip of the reflecting beds is utilized as an aid to correlation, and where structural relief is very steep, structure may be delineated solely by the determination of the angle of dip of the beds without the necessity of effecting a correlation.

Briefly, the method for determining the dip of a reflecting stratum is as follows. The shot point and seismometer positions are placed as shown in Figure 1. The path of the reflected energy arriving at seismometer No. 6 (OR_6S_6) is obviously greater than that of the energy arriving at seismometer No. 1 (OR_1S_1). The difference in these two paths is equal to the normal difference between the two paths if the reflecting bed were horizontal, plus the distance P_6S_6, since S_1N_1 may

[3] Eugene McDermott, "Application of Seismography to Geological Problems," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 11 (November, 1931), pp. 1311–34.

be considered equal to P_6N_6. As the velocity is known to a sufficient degree of accuracy, for any given difference in time of arrival of a reflected wave at seismometers No. 1 and No. 6, the distance P_6S_6 may be calculated. To a close approximation S_6P_6 may be considered perpendicular to S_1P_6. Since S_1S_6 is known, the angle θ which is equal to the angle of dip of the reflecting bed may be readily calculated. In actual routine practice the computations are made very quickly by means of charts, plotted from figures calculated in a manner involving no approximations.

FIG. 1.—Paths of reflected energy from sloping bed.

If the variations in the thickness of the weathered zone between seismometer locations are small, the velocity of propagation is accurately known, and two determinations are made at each shot position with the seismometers placed along two lines in opposite directions from the shot point, the angle of dip of the reflecting beds may be determined by this method with an accuracy of about 2°. Where the velocity is not accurately known, there will be introduced an additional error in the dip determination roughly equal to the product of the calculated dip and the percentage error in the velocity. For instance, if the velocity used in the calculations is in error by 10 per cent and the calculated angle of dip is 10°, then this figure will be in error

by about 1° due to the error in the velocity. In general, any error in the velocity is less than 10 per cent.

By plotting the depth determinations on a cross section along lines inclined at an angle equal to the corresponding angle of dip of the reflecting beds, as shown in Figure 2, and drawing lines through these points perpendicular to the above inclined lines, the correlation of the beds is effected almost automatically. That is, the correlation between any two points is limited to just one or two possibilities instead of many. Where a correlation of records may be made solely from a study of record character, the foregoing method may be utilized as a check on the correlation.

CORRELATION OF RECORDS

In considering the problems of reflection record correlation in California, the major areas of the state offering possibilities for reflection work may be divided into two general groups: Group I, those areas where the reflecting beds which may be utilized for the delineation of subsurface structure are of Cretaceous age or earlier; and Group II, those areas where the reflecting beds are of Eocene age or later.

In general, the reflecting strata in the areas of the first group persist throughout large regions and retain their physical characteristics from point to point, but in the second group, many of the reflecting beds either fail to persist over any large area or are subject to comparatively abrupt changes in their lithologic character. Consequently, while in the former the correlation of reflection records may be based entirely on record character, in many of the latter it is essential to determine the dip of the beds before a correlation may be effected with any degree of certitude.

The two principal areas of the first group are the Sacramento Valley and the upper part of the San Joaquin Valley. In the greater part of both these areas some of the reflecting beds in the Cretaceous section are found at desirable depths for use as markers to map subsurface structure. The Cretaceous section contains several well defined strata with sharp lithologic contrasts, and these in general act as very good reflectors of elastic waves. Thus reflection records secured in these two areas usually show a few clearly defined and outstanding reflected impulses, with distinctive groupings and character. Furthermore, since the reflecting horizons maintain their physical properties throughout comparatively large areas, the correlation of records offers little difficulty. Except where structure is very complex, angle determinations of dip are not essential, and of course, where the dips are

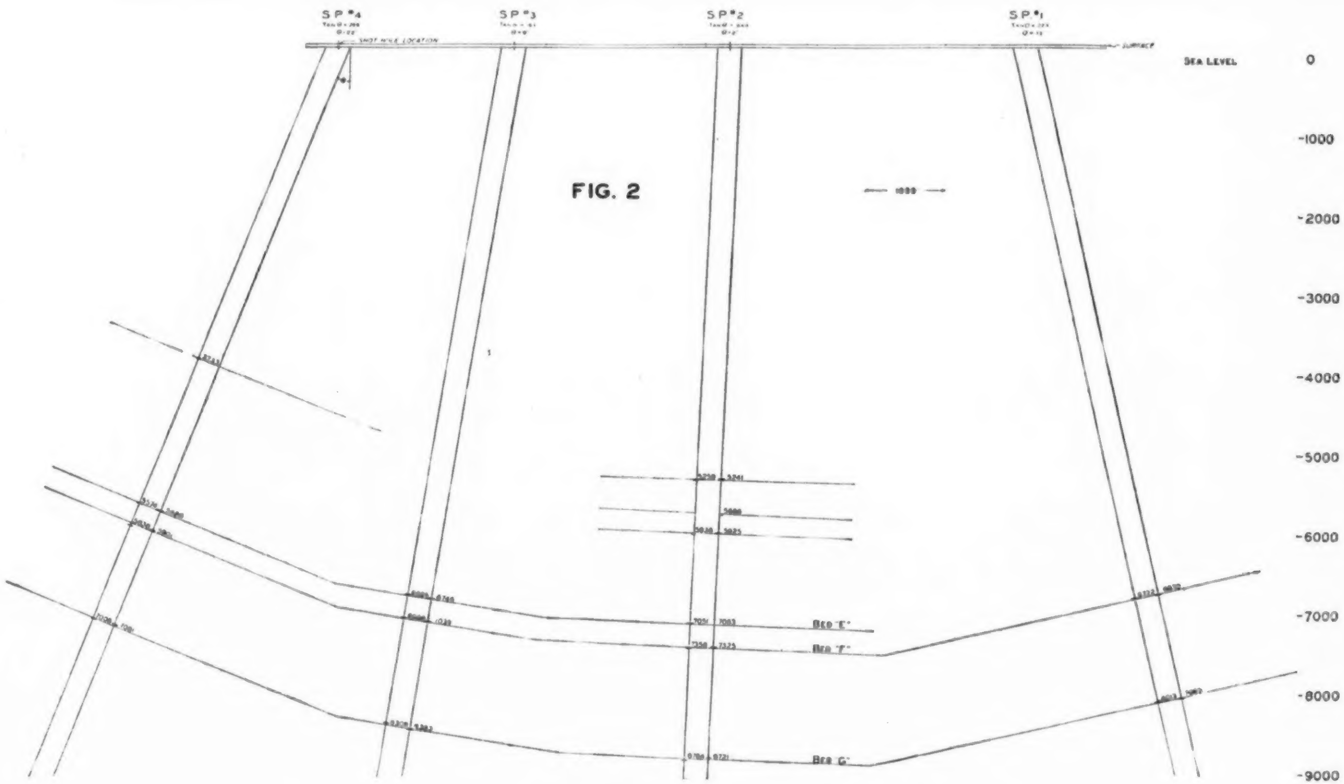

FIG. 2.—Cross section of syncline plotted from results obtained from records shown in Figure 3.

very gentle they can not be determined with sufficient accuracy to be of much value. Where beds are truncated in a region of structural uplift, this condition may be inferred, as a rule, by noting the disappearance of the key reflections.

In the upper part of the San Joaquin Valley, reflections from a bed in the Cretaceous were obtained throughout an area of more than 500 square miles and the correlation was effected with comparative ease. Figure 4 shows three reflection records obtained in this area at points spaced about 2 miles apart. As may be observed, the reflected impulse marked *A* is the dominant reflection on all three records and can be easily identified. These records may be considered typical of records which may be secured in the greater part of Sacramento and upper San Joaquin valleys.

The major areas in Group II are the lower half of San Joaquin Valley, Los Angeles Basin, Ventura Basin, Santa Maria Valley, Imperial Valley, Santa Clara Valley, and Salinas Valley. In these areas the most desirable reflecting horizons for mapping structure are ordinarily found in either the Pliocene, or Miocene, or both. In a few localities, reflecting beds in the Eocene may be utilized for mapping structure but, in general, this group may be designated as the Pliocene-Miocene group. Although the writer has had no experience in Imperial, Santa Clara, and Salinas valleys, these are included in this group from a consideration of their geologic sections.

As a rule, no difficulty is experienced in securing good reflections from several reflecting strata whenever the charges are properly planted. In fact, the chief characteristic of records secured in the areas of this group is the great number of reflections. However, since these reflections cannot always be depended upon to maintain their character and relative amplitude throughout a large area, it is usually desirable and oftentimes essential to determine the dip as well as the depth of the reflecting beds in order to effect a correlation of the records. By plotting the results on a cross section as described above, a correlation of the records may be usually effected.

In each of the areas of this group, there are probably several localities where sharply defined reflecting strata exist which are continuous throughout regions of large extent, and in those cases a correlation of the reflecting horizons may be effected without the aid of dip determinations. For example, in a reflection survey of a locality in the southern part of the San Joaquin Valley, excellent reflections were secured from two reflecting beds in the Etchegoin formation throughout an area of about 30 square miles. Although both dip and depth determinations were made at each shot point, it would have

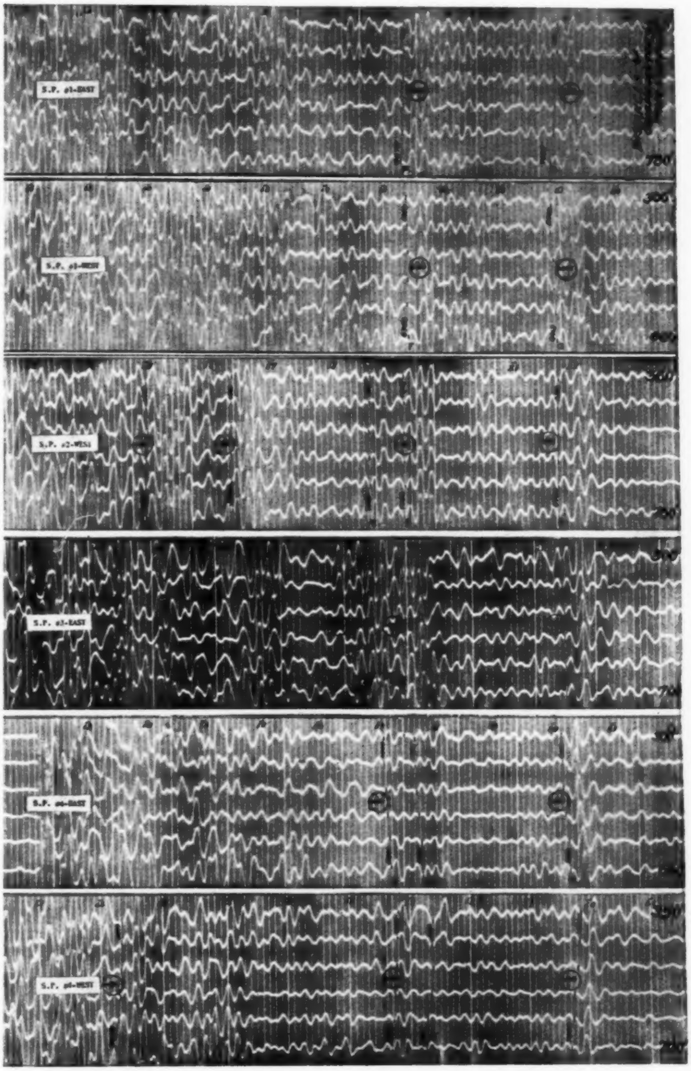

FIG. 3.—Typical reflection records of lower San Joaquin Valley.

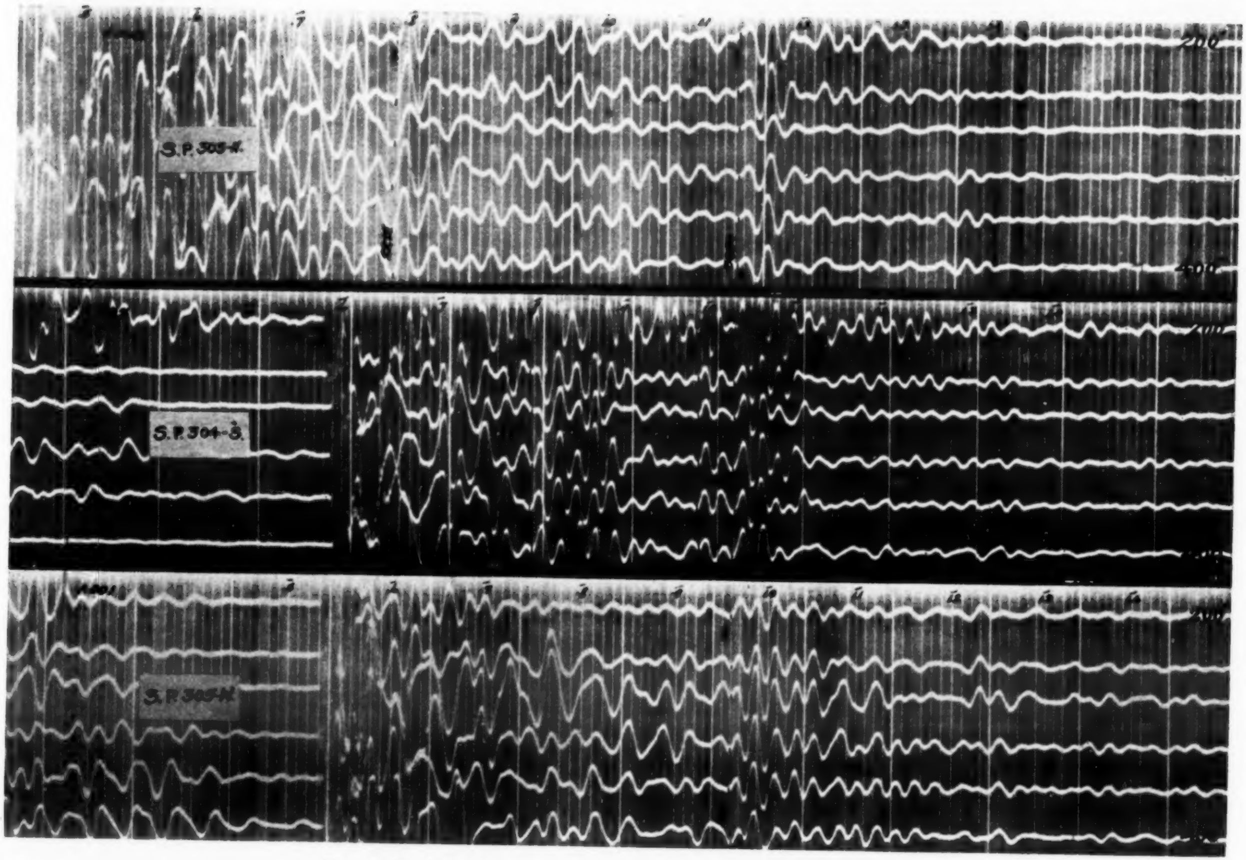

FIG. 4.—Typical reflection records secured in upper San Joaquin Valley.

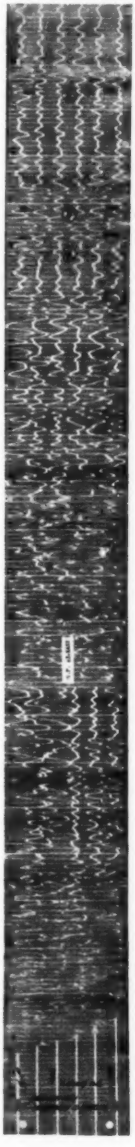

FIG. 5.—Complete reflection record of lower San Joaquin Valley. Part of this record is shown in Figure 3.

been possible to correlate the records readily throughout the entire area without the aid of the dip determinations. On the other hand, reflections from strata in this same formation secured only a few miles away had lost their unique character and a correlation of the records without a knowledge of the dip of the beds would have been open to serious doubts. It may, therefore, be stated that the determinations of the dip of the beds are an essential aid in the correlation of records in the greater part of the areas classified under Group II.

Figure 3 shows six reflection records obtained in the southern part of the San Joaquin Valley at four shot points spaced about ½ mile apart. Attention is called to the great number of reflections on these records as compared with the records shown in Figure 4. As already mentioned, this is typical of records secured in the areas of Group II. At each of these positions records were taken with the seismometers placed along two lines extending in opposite directions from the shot point. For shot positions No. 1 and No. 4 a record is shown for each direction of shot, while only one record is shown for each of the shot positions No. 2 and No. 3. In order to show the main reflections as clearly as possible, only the last half of each record is shown, thus permitting the use of a larger photographic scale. The record of shot point No. 3 is also shown in full in Figure 5.

Although there are a number of other reflections on these records, depth and dip figures have been calculated only for the more outstanding ones. The vertical depth figures for the corresponding reflections are shown near the lower edge of each record. The figures enclosed in circles indicate the difference in the travel time of the reflected energy arriving at seismometers No. 1 and No. 6, from which the dip of the reflecting beds is calculated. From an inspection of the records it may be observed that, for any given record, the difference in time of arrival of the reflected energy at seismometers No. 1 and No. 6 is very nearly the same for all reflections of approximately the same depth. Thus it is seen that while only the more outstanding reflections can be readily correlated from point to point, almost any reflection, regardless of its low amplitude or lack of unique character, can be utilized to determine the dip of the bed with an equal degree of accuracy.

The correlation of reflections designated *E*, *F*, and *G*, is, of course, apparent from an inspection of the records. These are reflections from strata in the Lower Etchegoin. They were obtained throughout the entire locality and readily correlated on the basis of their general appearance, amplitude interval, etc. In Figure 2 is shown a cross section on which have been plotted all the depth figures calculated from

the records shown in Figure 3. The average of the two determinations in opposite directions was used for plotting the dip of the beds at each point. Since the dip and depth of the beds are independently determined from different data, the close agreement in the lines drawn through the depth points of the different shot positions is an excellent check on the accuracy of the results.

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DISCUSSION

CHARACTER OF PRODUCING SANDSTONES AND LIMESTONES OF WYOMING AND MONTANA

In discussing the Embar and related formations of Wyoming in his article, "Character of Producing Sandstones and Limestones of Wyoming and Montana," in this *Bulletin*, Vol. 16, No. 9 (September, 1932), Bartram has postulated an unconformity occurring within the Phosphoria formation (pp. 870–73). He "believes that the Phosphoria, . . . , should be divided and the unconformity recognized."

Although the writer does not question the possibility of a mid-Phosphoria unconformity, for there remain many unexplained points regarding the formation, he believes that at present there is not sufficient evidence at hand to justify the recognition of an unconformity at this horizon, or to use it as a basis for dividing the formation into two parts. Unconformities not definitely proved to exist by their proponents have previously been postulated for this group of rocks. Nevertheless, these have become generally accepted and referred to by subsequent writers. A notable example is the problematical unconformity between the type Embar (Phosphoria and Dinwoody) and the red-bed phase known to oil geologists as Embar. This unconformity was postulated by Lee[1] and has been extensively quoted in the literature. Since Lee's work, its presence has been questioned, and, along with others, the writer believes that it probably does not exist. For these reasons it seems advisable, in the writer's opinion, not to accept the presence of a mid-Phosphoria unconformity until the time when more conclusive evidence can be presented.

Evidence advanced by Bartram for this unconformity is both paleontologic and lithologic. The paleontologic evidence consists of a statement that several paleontologists have reported Pennsylvanian faunas in the lower half of the formation. Branson[2] has recently made an extended study of the paleontology of the Phosphoria and has reached the conclusion that the age of the lower part is Pennsylvanian, that it grades upward into "Permo-Carboniferous," and that the upper part is early Permian. He compares the formation to the Pennsylvanian and Permian of Kansas which show a gradation without a break. King,[3] however, has more recently compared the fauna of the Phosphoria with that of the Word formation of Texas and believes that the Phosphoria is entirely Middle Permian in age.

Bartram quotes Girty to the effect that, "The fauna of the upper member of the Phosphoria (a limestone), . . . , differs strikingly from the fauna of the phosphatic shales." These different sedimentary rock types indicate different faunal environments and, for this reason, it is expectable, rather than unusual, to find that the faunule of the upper limestone of the Phosphoria is remarkably different from that of the phosphatic shales below. Even though

[1] Willis T. Lee, *U. S. Geol. Survey Prof. Paper 149* (1927).

[2] C. C. Branson, *Univ. Missouri Studies*, Vol. 5, No. 2 (1930).

[3] R. E. King, *Univ. Texas Bull. 3042* (1930), pp. 30–33.

the age of the formation is in controversy, there is at present, therefore, little paleontologic evidence of a break within the formation.

The presence of chert, phosphate beds, and porous dolomites is considered by Bartram as physical evidence of unconformity. Mansfield[1] has interpreted the chert of the Phosphoria as an original siliceous deposit. It should not be confused with chert replacements formed during a previous cycle of erosion. The layers of oölitic phosphate are believed to have been deposited as original phosphatic material[2] and were not formed as a result of leaching of carbonates from phosphatic limestones. The Phosphoria contains both phosphatic limestones and beds of phosphate rock which carry 70 per cent or less of tricalcium phosphate. It is probable that the factor which determined whether a given bed is now a phosphatic limestone or phosphate rock was the balance between the rate of deposition of carbonate material and the rate of deposition of tricalcium phosphate. The phosphate rock does not, therefore, imply a complete cessation of deposition, an essential condition for unconformity.

Porous dolomites in many places accompany unconformities, but are well known in conformable successions. The origins of this rock type are so variable that it, by itself, is of little or no value as evidence and should not be taken alone as a criterion of unconformity.

HORACE D. THOMAS[3]

UNIVERSITY OF WYOMING
LARAMIE, WYOMING
January 16, 1933

[1] G. R. Mansfield, *Econ. Geol.*, Vol. 26, No. 4 (1931), pp. 320–37.

[2] *Ibid.*, pp. 364–67.

[3] Introduced by John G. Bartram.

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REVIEWS AND NEW PUBLICATIONS

"Report of the Committee on Sedimentation, 1930–1932," *National Research Council Bull. 89*. Prepared under the auspices of the Division of Geology and Geography by W. H. Twenhofel, committee members, and others. (Washington, D. C., November, 1932.) 229 pp. Price, $1.00.

This two-year report, consisting of 22 separate reports, contains records of valuable original research by various investigators, and includes several useful bibliographic lists. Following is the table of contents.

(1) Introduction, W. H. Twenhofel; (2) The classification and terminology of the pyroclastic rocks, Chester K. Wentworth and Howel Williams; (3) Recent advances in the study of peat, W. E. Powers; (4) Studies of recent marine sediments conducted by the American Petroleum Institute, Parker D. Trask; (5) Experiments with the settling of bentonite in water, Edward M. Kindle; (6) The relation of the buffer mechanism of sea water to the solubility of calcium carbonate, D. M. Greenberg and E. G. Moberg; (7) Notes on investigations of modern marine sediments in California, Thomas Wayland Vaughan; (8) Bacterial and chemical factors in lime deposition at Tortugas, Florida, Haldane Gee; (9) Report on some work on sediments done in Germany in 1931, Hans Becker; (10) Varved sediments, Ernst Antevs; (11) Chert and flint, concretions, and cone-in-cone, W. A. Tarr; (12) Sedimentation studies at Stanford University, Eliot Blackwelder; (13) Study of the abrasional work of river ice and of glaciers, Chester K. Wentworth; (14) Chemical papers bearing on sedimentation, George Steiger; (15) Some recent applications of physics to sedimentation problems, C. E. Van Orstrand; (16) Investigations in ground water hydrology that bear on sedimentation, Arthur M. Piper; (17) Research on sediments by British scientists during 1930–1932, Henry B. Milner; (18) Recent studies with reference to the rôle of microörganisms in sediments, George A. Thiel; (19) Accessory minerals of crystalline rocks, Alexander N. Winchell, E. S. Larsen, J. C. Reed, J. T. Stark, A. C. Tester and J. F. Wright; (20) Abstracts of literature on accessory minerals of igneous rocks, J. C. Reed; (21) Abstracts of literature on accessory minerals in sedimentary rocks as related to possible source crystalline rocks, Allen C. Tester; (22) Studies in glacial sediments, 1930 and 1931, M. M. Leighton and Enid Townley.

Petroleum geologists will find in this report interesting and profitable information concerning many of the problems with which they have to deal. The introduction by Twenhofel is in the nature of a summary of papers published on various sedimentary problems. The following quotations have been taken from the Introduction.

> As originally defined, bentonite is rock composed of clay minerals produced by the alteration of volcanic ash . . . it is possible that there are some deposits with the properties of bentonite which were not derived from alteration of volcanic ash and hence do not have the significance of bentonite. Before a deposit is identified as bentonite it should be shown that it was derived *in situ* from volcanic ash.
>
> The writer is highly sympathetic to Professor Grabau's view of shallow water de-

position for the graptolite-bearing shales and for others similar in appearance but lacking graptolites, but he would postulate a slightly different shore environment.

It seems to be becoming apparent that more significance should be given to the possibility that some of the structures of ancient rocks usually interpreted as due to diastrophism may have been developed when the sediments were in soft condition.

Strictly anaerobic sulphate-reducing bacteria, which seem to be important in calcium carbonate precipitation, were found to exist everywhere. Bavendamm believes that calcium carbonate precipitation may be confined to certain localities and it is assumed "that mangrove swamps or similar places represent the natural localities for the micro-biological calcium carbonate precipitation." It is suggested that the precipitation occurs in brackish or fresh water.

It is pointed out that since sands tend to accumulate on topographic highs of the bottom, and the fine sediments in the topographic lows, there would be less compaction over the highs and more in the lows, thus tending to maintain a given structure for a long time over each high.

In the paper by Parker D. Trask, on "Studies of Recent Marine Sediments Conducted by the American Petroleum Institute," the following statements are made.

Deposits accumulating on ridges and relatively steep slopes are coarse-grained compared with those forming in adjacent valleys and closed basins. In Monterey Bay . . . sediments in 500 fathoms of water on a fairly steep slope consist of sand, but those in less exposed places nearer shore in much less shallow water consist of clay and silt. Similarly in Davis Strait, a sample from a relatively steep slope more than 100 miles from the coast is a fine sand, but sediments nearer shore in much shallower water are silts.

The organic content of sediments is influenced strongly by the configuration of the sea bottom. Deposits in depressions and closed basins contain more organic matter than do those on adjoining ridges and on slopes inclining more steeply than adjacent areas.

The organic content of sediments increases as the texture becomes finer. . . .

The organic content of typically marine sediments varies roughly with the supply of plankton in the surface water; . . .

Near-shore sediments contain much more organic matter than do those far from shore.

The organic content of sediments in regions of upwelling of deep water to the surface is large. Upwelling is believed to be caused by off-shore surface currents in coastal regions of considerable submarine relief. . . .

The organic content of deposits decreases from the surface downward. . . .

The data indicate that . . . sediments forming in quiet water are better sorted and have more symmetrical size distributions than those accumulating in disturbed water.

In the paper by Hans Becker on ". . . Some Work on Sediments Done in Germany in 1931," the following statements are made.

Dolomitization seems to take place in several ways. In a number of cases the dolomitization begins on the surface and extends downwards along fissures, . . . there is another type of dolomite which had been already altered a short time after the beginning of its deposition. This second type of dolomitization is the diagenetic type. The third way in which dolomite may be formed is through primary deposition.

Cherts of a given district and formation may have several distinct time relationships and modes of origin, as reviewed by Tarr in the paper on "chert and flint, concretions, and cone-in-cone." Three main varieties of chert are distinguished: one, contemporaneous with the containing limestone, and precipitated as a gel on the sea floor; the second, ". . . formed from the silica derived from surrounding rocks and . . . deposited after the containing limestone consolidated"; the third is "a very late replacement." Purdue and Miser "believe that the silica for the (Arkansas) novaculite was deposited in the sea by chemical precipitation." The present reviewer believes that the

several distinct time relationships and modes of origin of chert in a given district and formation should be considered in making long-range correlations from insoluble residues and in studying such widespread cherty formations as the "Mississippi lime."

Papers 19, 20, and 21 on the studies of accessory minerals in crystalline rocks, designed partially to "provide important information regarding the source (or possible sources) of the detrital constituents of the derived rocks," are of academic interest, only, to Mid-Continent geologists because studies in the Mid-Continent region have shown that the clastic sediments, even those directly overlying pre-Cambrian rocks, have been derived from preexisting sediments.

The last paper, "Studies in Glacial Sediments," has no direct bearing on problems confronting petroleum geologists.

The printing and paper in the "Report on Sedimentation" are good, and there are a few interesting illustrations. The reviewer believes that all geologists whose work deals primarily with sedimentary rocks should keep abreast of current sedimentary research as summarized in this report.

Fanny Carter Edson

Tulsa, Oklahoma
February 10, 1933

RECENT PUBLICATIONS

COLOMBIA

"Über Erdöl in Kolumbian, Südamerika" (Petroleum in Colombia, South America), by Karl Ermisch. *Kali, Verwandte Salze, und Erdöl* (Potash, Related Salts, and Petroleum), Vol. 26, No. 24 (December 15, 1932) and Vol. 27, No. 1 (January 1, 1933), 16 figs. Wilhelm Knapp, Halle, (Saale), Mühlweg 19.

FRANCE

Compte-Rendus des Séances du Groupe des Géologues Pétroliers de Strasbourg (Reports of Meetings of Petroleum Geologists of Strasbourg). A new publication; 6 numbers per year. Vol. 1, Nos. 1-2 (1932), includes: "Structure de la région gazifère de Vaux-en-Bugey" (Structure of the Gas Region of Vaux-en-Bugey, France), by J. Jung, pp. 3-5, Fig. 1; "Affleurements d'hydrocarbures en Turque d'Asie" (Outcrops of Hydrocarbons in Asiatic Turkey), by C.-R. Hoffman, pp. 6-8; "L'utilisation géologique des débris de forage à Pechelbronn" (Geologic Use of Drill Cuttings at Pechelbronn), by M. Orgeval, pp. 9-10; "Présentation d'une nouvelle carte magnétique de la plaine d'Alsace" (New Magnetic Map of the Plain of Alsace), by C. Alexanian, pp. 11-13, Fig. 2; List of Members, pp. 15-16. Address: M. R. Schnaebele, treasurer, Merckwiller-Pechelbronn (Bas-Rhin). Annual subscription, 25 Frs.

GENERAL

Guide Book of the Sixth Annual Field Conference (1932). Published by the Kansas Geological Society (412 Union National Bank Building, Wichita, Kansas). Contains road log, geologic descriptions, oil fields, correlation tables; areal geologic map of eastern Kansas and southeastern Nebraska on scale of 1:370,160; "A Reclassification of the Pennsylvanian System in the

Northern Mid-Continent Region," by R. C. Moore; "A Brief Discussion of the Bronson Group in Kansas," by J. M. Jewett; "An Index to the Stratigraphy of Eastern Kansas and Adjoining Areas," by W. A. Ver Wiebe and W. R. Vickery; "An Outline of the Pennsylvanian of the Appalachian Region," by Arthur Bevan; "A Pre-Chattanooga Sub-Aerial Map in Northeastern Kansas," by J. V. Howell; "Map of the Forest City Basin," by F. G. Holl; "A Geologic Cross Section from Western Missouri to Western Kansas," by Miss Betty Kellett. 125 pp., 118 illus., 3 maps. Size, 9 by 11½ inches. Leatheroid binding. Price, postpaid, $10.00.

Prospecting for Oil and Gas, by A. J. Kosygin. 240 pp., 164 figs. Size, 6×9 inches. Cloth. (Moscow, 1932.) In Russian.

GEOPHYSICS

Directions for the Use of the Askania Torsion Balance, by C. A. Heiland. 88 pp., 33 figs. 6×9 inches. Cloth. (American Askania Corporation, Houston, Texas, 1933.) Price, postpaid, $3.30.

"Études géologiques et prospections minières par les méthodes géophysiques" (Geological Research and Mining Prospecting by Geophysical Methods), by P. Geoffroy and P. Charrin. *Geol. Survey Algeria Bull. 1*, 4th ser., Geophysics (1932), 348 pp., 103 figs. 6½×10. Paper. (Ch. Béranger, 15, rue des Saints-Pères, Paris.) Price, 66 francs.

"A New Contribution to Subsurface Studies by Means of Electrical Measurements in Drill Holes," by C. and M. Schlumberger and E. G. Leonardon. *Amer. Inst. Min. Met. Eng. Tech. Pub. 503* (29 West 39th Street, New York, 1933). 18 pp., 8 figs.

MEXICO

"An Occurrence of Upper Cretaceous Sediments in Northern Sonora, Mexico," by N. L. Taliaferro. *Jour. Geol.*, Vol. 41, No. 1 (January–February, 1933), pp. 12–37; 7 figs., 1 table.

MISSOURI

Biennial Report of the State Geologist, by H. A. Buehler. Includes "Oil and Gas Pools of Western Missouri," by Frank C. Greene, 68 pp., 11 illus.; "The Geology of the Blue Springs Gas Field, Jackson County, Missouri," by Glenn G. Bartle, 64 pp., 4 illus.; "Magnetic Surveys," by J. G. Grohskoff and C. O. Reinoehl, 20 pp., 4 illus. Total report, 245 pp., 30 illus. 6×9 inches. Paper. (Missouri Bureau of Geology and Mines, Rolla, Missouri, 1933.)

NEW MEXICO

"Clastic Plugs and Dikes of the Cimarron Valley Area of Union County, New Mexico," by Ben H. Parker. *Jour. Geol.*, Vol. 41, No. 1 (January–February, 1933), pp. 38–51, 6 figs., 1 table.

"The Oil and Gas Resources of New Mexico," by Dean E. Winchester. *New Mexico School of Mines Bur. Mines and Mineral Resources Bull. 9* (Socorro, New Mexico, 1933). 223 pp., 11 figs., 33 pls. Size, 6×9 inches. Paper. Price, $1.50.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 17, NO. 3 (MARCH, 1933), PP. 274-324

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Ermil Leslie Caster, Shreveport, La.
Sidney A. Packard, A. E. Oldham, E. B. Baldwin

Charles Eugene Fralich, Bradford, Pa.
R. E. Somers, R. H. Johnson, Paul D. Torrey

Wayne V. Jones, Shreveport, La.
G. W. Schneider, J. Y. Snyder, Dugald Gordon

John L. Kalb, Maracaibo, Venezuela, S. A.
C. A. Baird, P. E. Nolan, J. B. Burnett

Enid Townley, Urbana, Ill.
Theron Wasson, M. M. Leighton, A. A. Langworthy

FOR ASSOCIATE MEMBERSHIP

Martin Napoleon Broughton, College Station, Tex.
John T. Lonsdale, F. B. Plummer, Frederick A. Burt

John Perryman Davidson, Wichita Falls, Tex.
H. F. Smiley, R. A. Birk, Fred M. Bullard

William Robert Ransone, Dallas, Tex.
Robin Willis, B. F. Hake, Theo. A. Link

FOR TRANSFER TO ACTIVE MEMBERSHIP

Stanley S. Siegfus, Coalinga, Calif.
E. F. Davis, Roy R. Morse, Art R. May

FINANCIAL STATEMENT, 1932

To the EXECUTIVE COMMITTEE,
THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS,
TULSA, OKLAHOMA

We have examined the accounting records of The American Association of Petroleum Geologists for the year ended December 31, 1932, from which the following statements have been prepared.

Exhibit

A Statement of Financial Condition as at December 31, 1932.
B Statement of Income for the year ended December 31, 1932.
C Statement of Income from Publications for the year ended December 31, 1932.
D Statement of General and Administrative Expenses for the year ended December 31, 1932.

Reserves of $4,800.40 have been provided for Accounts Receivable from Members and Others; Inventories of Printed Matter are at current appraised values and represent the supply of publications to meet anticipated requirements; Investments are stated at market value,—all as authorized by the Executive Committee.

In our opinion, the accompanying Statement of Financial Condition and relative Statements of Income and Expenses respectively correctly reflect the financial condition of The American Association of Petroleum Geologists at December 31, 1932, and the results of its operations for the year ended on that date.

(Signed) ARTHUR YOUNG & CO.
Accountants and Auditors

TULSA, OKLAHOMA
January 26, 1933

EXHIBIT A

STATEMENT OF FINANCIAL CONDITION AS AT DECEMBER 31, 1932

ASSETS	*Total*	*General Fund*	*Publication Fund*	*Research Fund*
CURRENT ASSETS:				
Cash in Banks:				
First National Bank and Trust Company	$10,130.23	$ 8,322.92	$ 1,784.81	$ 22.50
National Bank of Commerce	273.45	273.45	—	—
TOTAL CASH IN BANKS	$10,403.68	$ 8,596.37	$ 1,784.81	$ 22.50
Accounts Receivable:				
Members (Less Reserve for Doubtful Accounts $4,578.00)	$ 1,977.00	$ 1,977.00	$ —	$ —
Advertising (Less Reserve for Doubtful Accounts $162.00)	454.00	454.00	—	—
Printed Matter (Less Reserve for Doubtful Accounts $60.40)	347.11	243.36	103.75	—
Miscellaneous	13.60	13.60	—	—
TOTAL ACCOUNTS RECEIVABLE	$ 2,791.71	$ 2,687.96	$ 103.75	$ —
Inventory—At Current Appraised Values	$17,159.70	$16,073.10	$ 1,086.60	$ —
Accrued Interest Receivable (Less Reserve $270.83)	$ 644.17	$ 523.42	$ 97.63	$ 23.12
TOTAL CURRENT ASSETS	$30,999.26	$27,880.85	$ 3,072.79	$ 45.62
INVESTMENTS:				
Bonds and Savings Certificates—at Market Value (Cost $44,336.91)	$30,018.91	$18,205.98	$11,112.39	$700.54
Life Membership Investment Fund (Cost $613.30)	579.55	579.55	—	—
TOTAL INVESTMENTS	$30,598.46	$18,785.53	$11,112.39	$700.54
FIXED ASSETS:				
Furniture and Fixtures	$ 3,294.29	$ 3,294.29	$ —	$ —
Less: Reserve for Depreciation	1,512.76	1,512.76	—	—
TOTAL FIXED ASSETS	$ 1,781.53	$ 1,781.53	$ —	$ —
INTER-FUND BALANCES	$ —	$ 484.25	$ −484.25	$ —
PREPAID AND DEFERRED CHARGES:				
Prepaid Insurance	$ 51.36	$ 51.36	$ —	$ —
Geology of Natural Gas	235.25	—	235.25	—
Geology of California	299.00	—	299.00	—
Preliminary Costs on Structure Volume III	1.98	—	1.98	—
TOTAL PREPAID AND DE-	$ 587.59	$ 51.36	$ 536.23	$ —

LIABILITIES	*Total*	*General Fund*	*Publication Fund*	*Research Fund*
CURRENT LIABILITIES:				
Accounts Payable	$ 1,533.60	$ 1,533.60	$ —	$ —
Society of Economic Paleontologists and Mineralogists	10.00	10.00	—	—
TOTAL CURRENT LIABILITIES	$ 1,543.60	$ 1,543.60	$ —	$ —
DEFERRED INCOME:				
Active Membership Dues—1933	$ 2,175.00	$ 2,175.00	$ —	$ —
Associate Membership Dues—1933	270.00	270.00	—	—
Subscriptions to Bulletin—1933	1,551.45	1,551.45	—	—
Subscriptions to Bulletin—1934	10.80	10.80	—	—
Subscriptions for Bound Volume XVI	240.00	240.00	—	—
TOTAL DEFERRED INCOME	$ 4,247.25	$ 4,247.25	$ —	$ —
SURPLUS:				
Balance, December 31, 1931	$56,748.94	$42,400.48	$13,395.97	$952.49
Net Profit for the year ended December 31, 1932—Exhibit B	1,427.05	792.19	841.19	−206.33
Balance, December 31, 1932	$58,175.99	$43,192.67	$14,237.16	$746.16

EXHIBIT B

STATEMENT OF INCOME FOR THE YEAR ENDED DECEMBER 31, 1932

EXHIBIT B

STATEMENT OF INCOME FOR THE YEAR ENDED DECEMBER 31, 1932

	General Fund Members	Annual Dues			*Publication Fund*		*Research Fund*		*Total*	
OPERATING INCOME:										
DUES:										
Active Membership	1,572	$15.00		$23,580.00		$ —		$ —		$23,580.00
Associate Membership	392	10.00		3,918.00*		—		—		3,918.00
	1,964			$27,498.00		$ —		$ —		$27,498.00
Less: Transfer to Income from Bulletins—										
Active Membership			$12,576.00†		$ —		$ —		$12,576.00	
Associate Membership			3,136.00‡						3,136.00	
				15,712.00		—		—		15,712.00
				$11,786.00		—		—		$11,786.00
PUBLICATIONS—Net *Loss* Income—Exhibit C				−1,980.00		225.20		—		−1,754.80
CONVENTION RECEIPTS (NET)				—		1,282.73		—		1,282.73
TOTAL OPERATING INCOME				$ 9,806.00		$1,507.93		$ —		$11,313.93
GENERAL AND ADMINISTRATIVE EXPENSES—EXHIBIT D				11,094.11		87.98		—		11,182.09
Net Operating *Loss* Income				$−1,288.11		$1,419.95		$ —		$ 131.84
NON-OPERATING INCOME:										
Interest on Investments			$ 1,330.75		$ 574.69		$ 58.67		$ 1,964.11	
Profit on Sale of Liberty Bond			24.37		—		—		24.37	
Interest on Checking Account			212.78		14.05		—		226.83	
Miscellaneous			17.90		—		—		17.90	
TOTAL NON-OPERATING INCOME			$ 1,585.80		$ 588.74		$ 58.67		$ 2,233.21	
Less: Additional Reserve for Book Value of Securities			−494.50		1,167.50		265.00		938.00	
				2,080.30		−578.76		−206.33		1,295.21
Net Profit Transferred to Surplus—Exhibit A				$ 792.19		$ 841.19		$−206.33		$ 1,427.05

* Amount does not represent full amount of $10 per associate because one associate lacked $2 of complete payment.
† Amount represents transfer of $8 per active member.
‡ Amount represents transfer of $8 per associate member.

EXHIBIT C

STATEMENT OF INCOME FROM PUBLICATIONS FOR THE YEAR ENDED DECEMBER 31, 1932

	General Fund—Bulletins		Publication Fund		Total	
OPERATING INCOME:						
Dues Transferred—						
Active Membership		$12,576.00		$ —		$12,576.0
Associate Membership		3,136.00		—		3,136.0
		$15,712.00		$ —		$15,712.0
Sale of Bulletins—						
Subscriptions		3,471.10		—		3,471.1
Advertising		2,945.61		—		2,945.6
		$22,128.71		$ —		$22,128.7
Sale of Bound Volumes and Special Publications—						
Bound Volumes	$2,275.88		$ —		$ 2,275.88	
Back Numbers	590.57		—		590.57	
Indexes	42.60		—		42.60	
Alberta Symposium	79.02		—		79.02	
Geophysics Symposium	177.58		—		177.58	
Structure Volume II	368.31		—		368.31	
Continental Drift	—		153.36		153.36	
Structure Volume I	—		291.74		291.74	
Geology of California	—		28.00		28.00	
		3,533.96		473.10		4,007.0
TOTAL OPERATING INCOME		$25,662.67		$473.10		$26,135.7
OPERATING COSTS:						
Manager's Salary (Proportion)	$2,176.22		$ —		$ 2,176.22	
Editorial Salary	3,441.63		—		3,441.63	
Cost of Printing Bulletin	14,718.84		—		14,718.84	
Cost of Printing Separates	247.32		—		247.32	
Stencil Corrections and Mailing	233.11		—		233.11	
Binding Volumes XV, XVI	1,608.06		—		1,608.06	
Engraving	1,017.05		—		1,017.05	
Freight and Express	48.48		—		48.48	
Copyright Fees	22.52		—		22.52	
Cost of Moving Bulletin Printing	120.58		—		120.58	
Discount on Publications	36.97		44.51		81.48	
Postage—Bulletin	574.16		—		574.16	
Purchase of Back Numbers	20.00		—		20.00	
	$24,264.94		$ 44.51		$24,309.45	
INVENTORY:						
December 31, 1931	$19,450.83		$ 1,289.99		$20,740.82	
December 31, 1932	16,073.10		1,086.60		17,159.70	
Decrease	$3,377.73		$ 203.39		$ 3,581.12	
Total Cost of Publications Sold		27,642.67		247.90		27,890.
Net *Loss*—Income from Publications—Transferred to Exhibit B		$−1,980.00		$225.20		$−1,754

EXHIBIT D

STATEMENT OF GENERAL AND ADMINISTRATIVE EXPENSES FOR THE YEAR ENDED DECEMBER 31, 1932

GENERAL FUND:	
Manager's Salary (Proportion)	$ 2,176.23
Clerical Salaries	4,658.13
Office Rent	300.00
Telephone and Telegraph	197.73
Postage—General	479.33
Printing and Stationery	461.55
Office Supplies and Expense	197.68
Insurance	177.40
Audit Fee	150.00
Custodian's Fee, Irving Trust Company	20.72
Freight and Express	6.96
Tax on Checks	2.72
Exchange and Refunds	10.55
Donations to Society of Economic Paleontologists and Mineralogists	368.00
Donation to 1933 International Geological Congress	500.00
Constitution Expense	212.49
Work on Association Seal	24.00
Houston Meeting	8.51
Miscellaneous	5.00
Bad Debts	807.68
Depreciation of Office Furniture and Fixtures	329.43
TOTAL—GENERAL FUND	$11,094.11
PUBLICATION FUND:	
Bad Debts	87.98
TOTAL—TRANSFERRED TO EXHIBIT B	$11,182.09

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
MEMBERSHIP LIST

FEBRUARY 1, 1933

HONORARY MEMBERS

The executive committee may from time to time elect as honorary members persons who have contributed distinguished service to the cause of petroleum geology. Honorary members shall not be required to pay dues—*Sec. 6, Article III, of the Constitution.*

LIFE MEMBERS

The executive committee may grant life membership to members who have paid their dues and are otherwise qualified.—*Sec. 2, Article III, of the Constitution.*

On the payment of three hundred dollars ($300.00) any member in good standing shall be declared a life member and thereafter shall not be required to pay annual dues.—*Sec. 2, Article I, of the By-Laws.*

MEMBERS

Any person engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership, provided he is a graduate of an institution of collegiate standing, in which institution he has done his major work in geology, or in sciences fundamental to petroleum geology, and in addition has had the equivalent of three years' experience in petroleum geology or in the application of these other sciences to petroleum geology or to research in petroleum geology or technology; and provided further that in the case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee; and provided further that these requirements shall not be construed to exclude teachers and research workers in recognized institutions whose work is of such character as in the opinion of the executive committee shall qualify them for membership.

Active members alone shall be known as members.—*Sec. 1, Article III, of the Constitution.*

ASSOCIATES

Any person having completed as much as thirty hours of geology (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalent to this, is eligible to associate membership, provided at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing, or shall be engaged in petroleum geology; and any person who is a graduate of an institution of collegiate standing, in which he has done his major work in sciences fundamental to petroleum geology or petroleum technology, and who has the equivalent of one year's experience in the application of his science to the study of petroleum geology, shall be eligible to associate membership, provided at the time of his application for membership he shall be engaged in investigations in the broader subject of petroleum geology and technology.

Associate members shall be known as associates.

Associates shall enjoy all the privileges of membership in the Association, save that they shall not hold office, sign applications for membership, or vote; neither shall they have the privilege of advertising their affiliation with the Association in professional cards or professional reports or otherwise.—*Sec. 3, Article III, of the Constitution.*

HONORARY MEMBERS

(**Deceased)

Decker, Charles E., 508 Chautauqua Ave., Norman, Okla.
**Dumble, E. T.
Goodrich, Harold B., 1628 S. Cincinnati, Tulsa, Okla.
Hill, Robert T., H tel Commodore, Los Angeles, Calif.
Orcutt, W. W., Union Oil Company Bldg., Los Angeles, Calif.
**Salisbury, R. D.
Smith, George Otis, Federal Power Commission, Interior Bldg., Washington, D.C.
**Udden, Johan August
**von Höfer, Hans Hofrat
White, David, U. S. Geological Survey, Washington, D.C.
**White, I. C.

COMPLETE LIST OF MEMBERS, ASSOCIATES, HONORARY MEMBERS, AND LIFE MEMBERS

Honorary	6
Life	2
Members	1,905
Associates	601
Total	2,514

EXPLANATION OF SYMBOLS

*Honorary member. †Life member. ‖Associate. Members are not marked. The year refers to the date of election to the Association, not necessarily to class of membership.

‖Abbott, John L., 1007 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. '27
‖Abell, George T., Midland, Tex. '29
Abrahamson, H., 3708 W. Fifth St., Fort Worth, Tex. '18
Abruns, Harry W., 259 S. Harvard St., Los Angeles, Calif. '27
‖Absher, Kenneth B., Box 543, Wichita, Kan. '25
Absher, William F., Empire Gas & Fuel Co., Geological Dept., Bartlesville, Okla. '20
Ackers, A. L., Stanolind Oil & Gas Co., Box 758, Midland, Tex. '25
Adams, Frank C., The Texas Co., Houston, Tex. '27
Adams, H. H., 1937 Chatbourn Court, Fort Worth, Tex. '19
Adams, John Emery, Drawer R., Midland, Tex. '29
Adams, Lowell A., 2117½ Palm Grove Ave., Los Angeles, Calif. '31
‖Adams, Theodore F., Kappa Sigma House, Golden, Colo. (Mail returned) '29
Adams, W. C., Deep Rock Oil Corp., Atlas Life Bldg., Tulsa, Okla. '24
Addison, Carl C., 3032 N. Twenty-First St., Kansas City, Kan. '30
Adkins, W. S., Bureau of Economic Geology, Univ. of Texas, Austin, Tex. '20
Adler, Joseph L., 135 Agate St., Houghton, Mich. '30
Aguerrevere, Pedro I., Sur 3, No. 94, Caracas, Venezuela, S. A. '24
Aguerrevere, Santiago E., Sur 3, No. 94, Caracas, Venezuela, S. A. '24
Aid, Herbert, Taylor Refg. Co., Taylor, Tex. '28
Aimer, James D., Box 375, Nacogdoches, Tex. '26
Ainsworth, David, 604 N. Fountain Ave., Wichita, Kan. '23
Ainsworth, William L., 301 N. Yale St., Wichita, Kan. '21
Aitken, William E., Oil & Gas Bldg., Univ. of Pittsburgh, Pittsburgh, Pa. '32
Albertson, Maurice M., Shell Petr. Corp., Box 2099, Houston, Tex. '20
Albrecht, Helmuth, Burbach-Kaliwerke Aktiengesellschaft, Kaiser-Otto-Ring 25, Magdeburg, Germany '32
‖Alcorn, Avary Hunt, 602 Citizens Natl. Bank Bldg., Tyler, Tex. '32
Aldrich, G. Frank, 2024 Wilshire Blvd., Fort Worth, Tex. '25
‖Aldridge, Mort B., Ramsey Petr. Corp., 18th Floor Petroleum Bldg., Oklahoma City, Okla. '27
‖Alexander, A. E., 159 Goulding Ave., Buffalo, N. Y. '31
Alexander, A. M., 18 E. One Hundred Ninety-Ninth St., New York, N. Y. '31
Allan, John Andrew, Univ. of Alberta, Edmonton, Alta., Canada '30

Allan, Thos. H., Stanolind Oil & Gas Co., 417 First Natl. Bank Bldg., Wichita, Kan. . . . '24
Allen, Bryant, Box 12, Laredo, Tex. . . . '25
Allen, Devere F., 135 S. Courtland, Topeka, Kan. . . . '29
Allen, Donald M., 1621 Keeler Ave., Bartlesville, Okla. . . . '24
Allen, E. G., Shell Petr. Corp., Box 2099, Houston, Tex. . . . '17
Allen, Walter J., Box 2203, Tulsa, Okla. . . . '18
Allison, A. P., Box 81, Lufkin, Tex. . . . '21
Althaus, H. E., Astra Romana, Campina, Roumania . . . '28
Ambrose, A. W., Empire Gas & Fuel Co., Bartlesville, Okla. . . . '19
Ames, Edward W., Box 169, San Antonio, Tex. . . . '19
Anderson, Amil A., 6075 Franklin Ave., Hollywood, Calif. . . . '22
Anderson, Carl B., 1131 S. Owasso, Tulsa, Okla. . . . '19
Anderson, Carl C., Box 2025, Amarillo, Tex. . . . '32
Anderson, Frank M., 58 Hillcrest Road, Berkeley, Calif. . . . '24
Anderson, G. E., 645 Lahoma, Norman, Okla. . . . '24
Anderson, J. L., Tropical Oil Co., El Centro, Colombia, S. A. . . . '29
Anderson, Lyman P., 1631 W. Twenty-Ninth St., Oklahoma City, Okla. . . . '27
||Anderson, Richard S., Drawer 2040, Tulsa, Okla. . . . '31
Anderson, Warren D., Box 832, San Angelo, Tex. . . . '27
Andrau, E. W. K., Shell Petr. Corp., Box 2099, Houston, Tex. . . . '32
Andreen, Harry M., Box 801, Tulsa, Okla. . . . '27
||Andrews, Hugh, Stratford, Okla. . . . '30
Andrews, Philip, 1675 Euclid Ave., Berkeley, Calif. . . . '25
Andrews, Sylvan H., 421 Philcade Bldg., Tulsa, Okla. . . . '20
||Angle, W. M., Box 731, Tyler, Tex. . . . '30
Apfel, Earl T., Syracuse University, Geological Dept., Syracuse, N. Y. . . . '29
Applin, Paul L., 2200 Edwin Ave., Fort Worth, Tex. . . . '19
Argabrite, William Graeme, Box 33, Lewisburg, W. Va. . . . '28
||Arick, Millard B., Box 938, McCamey, Tex. . . . '27
||Armor, Mildred V., 3711 Classen Blvd., Oklahoma City, Okla. . . . '30
Armstrong, Earle N., 3902 Cheyenne Road, Amarillo, Tex. . . . '33
Armstrong, Harold K., Room 838, 727 W. Seventh St., Los Angeles, Calif. . . . '27
Armstrong, J. M., Prairie Oil & Gas Co., Eastland, Tex. . . . '18
Arnett, Clarence L., 301 S. Eighth St., Ponca City, Okla. . . . '27
Arnold, Emmett L., 1128 S. Elgin, Tulsa, Okla. . . . '27
Arnold, Harry H., Jr., 602 W. Dewey St., Shawnee, Okla. . . . '27
||Arnold, Henry C., Box 97, Earlsboro, Okla. . . . '30
Arnold, Ralph, 1201 E. California St., Pasadena, Calif. . . . '18
Aronson, Sam M., Atlantic Oil Prod. Co., 701 Magnolia Bldg., Dallas, Tex. . . . '24
Artman, George W., 2733 N. W. Seventeenth St., Oklahoma City, Okla. . . . '25
||Atchison, J. Wilbur, Pure Oil Co., Box 1007, Fort Worth, Tex. . . . '31
Athy, Lawrence F., Continental Oil Co., Geophysical Division, Ponca City, Okla. '26
Atkinson, William H., 26th Floor Ramsey Tower, Oklahoma City, Okla. . . . '22
Atwill, E. R., Box 126, San Gabriel, Calif. . . . '31
Aurand, Harry A., 1350 Bellaire St., Denver, Colo. . . . '26
Aurin, Fritz L., Southland Royalty Co., Ponca City, Okla. . . . '17
Autry, Vernon E., Humble Oil & Refg. Co., Box 1034, Wichita Falls, Tex. . . . '26
Avery, C. Dwight, U. S. Geological Survey, 3240 Interior Bldg., Washington, D.C. . . . '28
||Ayers, Floyd M., Sabetha, Kan. . . . '30

Bace, A. C., Stanolind Oil & Gas Co., Philcade Bldg., Tulsa, Okla. . . . '24
Bacon, Charles S., Jr., Riverside Junior College, Geological Dept., Riverside, Calif. . '29
Baden, Martin W., Box 520, Winfield, Kan. . . . '21
Bagg, Rufus M., Box 386, Appleton, Wis. . . . '27
||Bailey, Donald G., 798½ Kensington Road, Los Angeles, Calif. . . . '31
Bailey, James P., N. V. Ned. Pac. Petr. Mij., Prinsenstraat, hoek Stradhuisplein, Batavia, Java, D. E. I. . . . '31
||Bailey, Joe, 1201 E. Eleventh St., Winfield, Kan. . . . '30
Bailey, Thomas L., Box 713, Ventura, Calif. . . . '24
Bain, H. Foster, Copper & Brass Research Assoc., 25 Broadway, New York, N. Y. '26

Baird, Chester A., Venezuela Gulf Oil Co., Apartado 234, Maracaibo, Venezuela, S. A. .... '21
Baker, Arthur A., U. S. Geological Survey, Washington, D.C. .... '30
||Baker, Lara H., 542 Wall St., Shreveport, La. .... '29
Baker, Norval E., Room 1567, 26 Broadway, New York, N. Y. .... '27
Baker, Raymond F., The Texas Co., Geological Dept., 135 E. Forty-Second St., New York, N. Y. .... '17
Baker, William A., Jr., Huasteca Petr. Co., Apartado 94, Tampico, Tamps., Mexico '24
||Bakke, W. E., North Penn Gas Co., 206 Broad St., Port Allegany, Pa. .... '28
Baldwin, E. B., Bellville, Austin County, Tex. .... '29
Bale, Hubert E., 701 Continental Bldg., Oklahoma City, Okla. .... '24
Ball, Max W., 715 First Natl. Bank Bldg., Denver, Colo. .... '19
||Ballard, Andrew L., 1518 Alamo Natl. Bldg., San Antonio, Tex. .... '21
Ballard, James L., Drawer F., Houston, Tex. .... '25
||Ballard, William Norval, 1204 Petroleum Bldg., Oklahoma City, Okla. .... '29
||Banks, Overton B., 2250 Neches St., Beaumont, Tex. .... '30
Banks, Thomas R., Magnolia Petr. Co., 2110 Alamo Natl. Bldg., San Antonio, Tex. .... '27
Barbat, William F., Standard Oil Co., Taft, Calif. .... '28
Bard, Richards J., Wayne, Pa. .... '28
||Barksdale, J. D., Box 2311, Stanford University, Calif. .... '31
||Barling, Robert, 606 Milam Bldg., San Antonio, Tex. (Mail returned) .... '27
Barlow, Victor, 121 N. Hill St., Los Angeles, Calif. .... '27
Barnes, Roy M., Continental Oil Co., 417 S. Hill St., Los Angeles, Calif. .... '24
||Barnes, Virgil E., 1815 Avenue I, Galveston, Tex. .... '31
Barnett, D. G., United Production Corp., Geological Dept., Houston, Tex. .... '25
||Barnett, J. A., 228 Centre St., Dallas, Tex. .... '28
||Barney, Arthur Y., Piney Oil & Gas Co., 1139 Milam Bldg., San Antonio, Tex. .. '30
Barnhart, Carl F., Weatherford, Okla. .... '29
Barnwell, George F., Ned. Kol. Petr. Mij., The Hague, Holland .... '28
||Barragy, Edward J., Rockwell, Iowa .... '31
Barret, William M., 2524 Fairfield Ave., Shreveport, La. .... '32
||Barrett, Albert F., Box 146, Parco, Wyo. .... '30
||Barrett, Claude L., Twin State Oil Co., Tulsa, Okla. .... '28
Barrett, Morris K., Box 181–A, Wheatridge, Colo. .... '27
Barrow, Geoffrey, 344 Robin Hood Lane, Hall Green, Birmingham, England ..... '31
Barrow, Leonidas T., 3314 Chevy Chase, River Oaks, Houston, Tex. .... '22
Bartell, Laurence D., East Texas Refg. Co., Longview, Tex. .... '27
Barth, William A., Imperial Oil & Gas Products Co., Owensboro, Ky. .... '23
Bartle, Glenn G., Kansas City Junior College, Kansas City, Mo. .... '27
||Bartle, Ronald L., 2112 N. Villa, Oklahoma City, Okla. (Mail returned) .... '28
Bartlett, C. Lothrop, Sun Oil Co., Beaumont, Tex. .... '28
Bartlett, Fred W., Shell Petr. Corp., Box 2099, Houston, Tex. .... '24
Barton, Donald C., Petroleum Bldg., Houston, Tex. .... '20
Barton, Louis A., Box 433, Shreveport, La. .... '20
Bartram, John G., Stanolind Oil & Gas Co., Casper, Wyo. .... '17
||Bartram, Paul L., Box 176, Aspermont, Tex. (Mail returned) .... '27
Barwick, John S., 510 S. Pearl, Paola, Kan. .... '24
Bass, N. W., U. S. Geological Survey, Wichita, Kan. .... '25
Bassett, Charles F., Univ. of Michigan, 1526 University Museum, Ann Arbor, Mich. '28
Bassler, Harvey, c/o Samuel Mosser, Myerstown, Pa. .... '28
Bateman, Alan M., Drawer C, Yale Station, New Haven, Conn. .... '20
||Bates, R. P., 404 Springer Bldg., Tulsa, Okla. .... '30
Bauer, C. Max, Box 236, Yellowstone Park, Wyo. .... '17
Bauermann, Max K. H., Carel van Bylandtlaan 30, The Hague, Holland .... '27
Bauernschmidt, A. J., Jr., Union Sulphur Co., Sulphur La., ... '27
Bauserman, E. V. H., 308 Federal Bldg., Dallas, Tex. .... '26
||Bay, Harry X., Cole Camp, Mo. .... '30
Bayer, H. M., Box 968, Midland, Tex. .... '25
||Bayle, Pierre, Caribbean Petr. Co., Maracaibo, Venezuela, S. A. .... '31
Beal, Carl H., 650 S. Grand Ave., Los Angeles, Calif. .... '19
||Bean, John M., Elwood, Neb. .... '30
Bean, Ward C., Box 1191, Tulsa, Okla. .... '18

Beatty, Robert M., Box 239, Houston, Tex. .... '27
||Beck, August F., 1620 S. Troost, Tulsa, Okla. (Mail returned) .... '27
Beck, Elfred, 506 N. Quanah, Tulsa, Okla. .... '20
Beck, N. C., 1009 N. Spring St., Tyler, Tex. .... '30
Beckelhymer, Roy L., 2235 Robinhood St., Houston, Tex. .... '26
Becker, Clyde M., 224 S. Fourteenth St., Chickasha, Okla. .... '21
Beckwith, H. T., 547 Subway Terminal Bldg., Los Angeles, Calif. .... '21
Beede, J. W., Route 2, Spencer, Ind. .... '19
Beekly, Albert L., Box 381, Tulsa, Okla. .... '19
Beers, Roland F., 1311 Republic Bank Bldg., Dallas, Tex. .... '31
Behre, Charles H., Jr., Northwestern University, Evanston, Ill. .... '29
||Beilharz, Carl F., Pure Oil Co., Gueydan, La. .... '27
Belknap, Ralph L., Univ. of Michigan, Ann Arbor, Mich. .... '31
Bell, Alfred H., State Geological Survey, Urbana, Ill. .... '28
Bell, Harry Wesley, Lion Oil Refg. Co., Exchange Bldg., El Dorado, Ark. .... '22
Bell, John, 31 Cottage Lane, Gamesley, Glossop, Derbyshire, England (Mail returned) .... '24
Bell, Olin G., Box 548, Laredo, Tex. .... '20
Belluigi, Arnaldo, Via Vitt. Em. 178, Parma, Italy .... '31
Belt, Ben C., 3451 Del Monte Drive, Houston, Tex. .... '19
||Benderoff, Vassili C., Box 464, Springfield, Colo. (Mail returned) .... '27
Bending, Ralph E., Y.M.C.A., Wichita, Kan. .... '25
Benedum, Darwin, 414 W. Elsmere Place, San Antonio, Tex. .... '27
Bennett, Clyde M., Magnolia Petr. Co., Dallas, Tex. .... '18
||Benson, Don G., Box 104, Greeley, Kan. .... '31
||Benson, Edmund T., State Geological Survey, Urbana, Ill. .... '31
||Benson, Floyd P., 515 E. Oklahoma, Blackwell, Okla. .... '31
Bentley, B. Howard, 708 San Angelo Natl. Bank Bldg., San Antonio, Tex. (Mail returned) .... '30
Benton, Louis B., 1730 Sixth Ave., Fort Worth, Tex. .... '20
Bentz, Ivan V., 424 W. Twenty-Ninth St., Kearney, Neb. .... '25
Berger, Walter R., 1005 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. .... '17
Bernard, W. E., Box 661, Tulsa, Okla. .... '21
Bernoulli, W., 57 Sissacherstrasse, Basle, Switzerland .... '24
Berry, Hally L., Venezuelan Sun Co., Ltd., Apartado 34, Maracaibo, Venezuela, S. A. .... '27
||Berry, Harry L., Box 836, Cushing, Okla. .... '30
||Berry, Jack J., Box 836, Cushing, Okla. .... '30
Berwald, W. B., U. S. Bureau of Mines, Bartlesville, Okla. .... '23
Best, J. Boyd, Route 1, Box 420, Houston, Tex. .... '21
Bevier, George M., 609 Sterling Bldg., Houston, Tex. .... '21
Bickel, C. Russell, Shell Petr. Corp., Box 417, McPherson, Kan. .... '27
Bierman, Alfred C., Fain-McGaha Oil Corp., 607 Hamilton Bldg., Wichita Falls, Tex. .... '19
Bingham, Dwight H., c/o Bingham Clothing Co., Junction City, Kan. .... '21
||Bingman, Neal J., Box 4, Midland, Tex. (Mail returned) .... '30
Biraud, Francois, Cie, Francaise des Petroles, 9 Square de Messine, Paris, France .... '31
||Birdsong, P. M., 1522 Grand Ave., Fort Worth, Tex. .... '30
Birk, Ralph A., 811 City Natl. Bank Bldg., Wichita Falls, Tex. .... '20
Birkett, Donald S., 813 Linwood Ave., Louisville, Ky. .... '27
Birkhauser, Max, Box 345, Oilfields, Calif. .... '26
||Black, Jo Pat, Gulf Prod. Co., Drawer C, Houston, Tex. .... '32
||Blackburn, Willis C., Humble Oil & Refg. Co., 204 Nixon Bldg., Corpus Christi, Tex. .... '28
Blackwelder, Eliot, Box N, Stanford University, Calif. .... '19
Blanchard, J. B., Marshall Hotel, Marshall, Tex. .... '31
Blanchard, W. Grant, Jr., 3609 Potomac, Dallas, Tex. .... '18
Blanpied, B. W., Drawer 1731, Shreveport, La. .... '23
||Blau, Ludwig W., 2027 Colquitt, Houston, Tex. .... '30
Bleecker, Edward S., 1615 Whitehall Bldg., 17 Battery Place, New York, N. Y. .... '21
Blodget, Ward B., 707 Petroleum Securities Bldg., Tenth & Flower Sts., Los Angeles, Calif. .... '24
Bloesch, Edward, 840 Kennedy Bldg., Tulsa, Okla. .... '17

||Boehms, E. F., 214 S. Madison St., San Angelo, Tex. ... '31
Boggs, Oliver D., Negritos, Talara, Peru, S. A. ... '26
Bohart, Philip H., Apartado 106, Tampico, Mexico ... '23
Bohdanowicz, Charles, Str. Polna 64, Warsaw, Poland ... '31
Bolyard, Garrett L., 308 Peoples Natl. Bank Bldg., Tyler, Tex. ... '27
||Bond, Marshall, 328 E. Islay St., Santa Barbara, Calif. ... '24
Bong, Carl P., 3417 Fourth Ave., Los Angeles, Calif. ... '27
Boos, C. Maynard, 430 N. Lake St., Madison, Wis. ... '26
Boos, E. J., 610 Ellis-Singleton Bldg., Wichita, Kan. ... '27
Borden, Joseph L., Box 271, Tulsa, Okla. ... '27
Borden, S. P., 721 Slattery Bldg., Shreveport, La. ... '24
Born, W. T., 15 Ward St., Bloomfield, N. J. ... '32
Bornhauser, Max, Superior Oil Co., 4614 Montrose Blvd., Houston, Tex. ... '28
Borst, O. H., c/o Harris & Haun, Inc., Blackwell, Okla. (Mail returned) ... '28
Bossard, Leon, "Wharetui," Chemin de Vallauris, Antibes, A. M., France ... '29
Bossler, Robert B., 102 Grant Court, Olean, N. Y. ... '21
Bostick, J. Wallace, 4648 Waneta Drive, Dallas, Tex. ... '19
Bowen, Charles F., Room 1560, 26 Broadway, New York, N. Y. ... '20
Bowen, James P., Panhandle Refg. Co., Wichita Falls, Tex. ... '18
||Bowen, Lot, 347 N. Crescent Heights Blvd., Los Angeles, Calif. ... '25
Bower, John O., Escritorio 724, Calle Florida 229, Buenos Aires, Argentina, S. A. '29
Bowes, Glenn H., 731 Garfield Ave., S. Pasadena, Calif. ... '24
Bowles, R. C., 1215 McCullough Ave., San Antonio, Tex. ... '27
||Bowling, Leslie, 717 Patterson Ave., Austin, Tex. ... '30
Bowman, Francis F., Jr., Cedarwood Farm, Madison, Wis. ... '29
Bowman, Wayne F., 1741 W. Main St., Houston, Tex. ... '19
||Bowser, W. F., Box 341, San Angelo, Tex. ... '27
Boyd, Harold, Henry Doherty & Co., 60 Wall St., New York, N. Y. ... '17
||Boyd, W. Baxter, 1224 W. Thirty-First St., Oklahoma City, Okla. ... '29
Boyer, Will W., 401 Consolidated Royalty Bldg., Casper, Wyo. ... '28
Boylan, Ebert E., Caracas Petr. Corp., Apartado 587, Caracas, Venezuela, S. A. ... '19
Boyle, Albert C., Jr., Union Pacific System, 305 Custer St., Laramie, Wyo. ... '23
||Boyle, George R., 1020 W. Twentieth St., Oklahoma City, Okla. ... '20
||Boyle, Huron L., McGregor, Iowa ... '31
Boyle, Walter J., 731 S. Spruce St., Wichita, Kan. ... '26
||Boyles, James M., 2006 Gulf Bldg., Houston, Tex. ... '31
Brace, Orval L., 2104 Bissonet St., Houston, Tex. ... '19
||Bradfield, Herbert H., Indiana University, Geological Dept., Bloomington, Ind. ... '27
Bradish, Ford, 2005 Fort Worth Natl. Bank Bldg., Fort Worth Tex. ... '19
Bradley, Everett L., 709 Bitting Bldg., Wichita, Kan. ... '22
Braendlin, Emil, P. O. Box 57, Miri, Sarawak via Singapore, Borneo ... '32
Brainerd, Arthur E., Continental Oil Co., Denver, Colo. ... '22
Brainerd, William F., Box 912, San Angelo, Tex. ... '26
Bramlette, Milton N., U. S. Geological Survey, Washington, D. C. ... '25
||Brankstone, Hugh R., 1256 McNeilly Ave., Pittsburgh, Pa. ... '32
Branner, Geo. C., 447 State Capitol Bldg., Little Rock, Ark. ... '21
Branson, E. B., Univ. of Missouri, Columbia, Mo. ... '25
Brant, Ralph A., Atlantic Oil Prod. Co., 510 Beacon Life Bldg., Tulsa, Okla. ... '26
Brantly, John E., 25 Broadway, New York, N. Y. ... '18
||Brasted, Fred, Jr., Stanolind Oil & Gas Co., Shawnee, Okla. ... '30
Brauchli, Rud., Anderson-Prichard Oil Corp., Colcord Bldg., Oklahoma City, Okla. '23
Braugh, Donald D., Box 804, Troup, Tex. ... '21
Brehm, Ralph C., 1407 S. Guthrie, Tulsa, Okla. ... '27
||Breitenstein, Robert S., c/o D. E. Park, Escrit. 724, Calle Florida 229, Buenos Aires, Argentina, S. A. ... '29
||Bremer, Bernhard E., Box 1737, Shreveport, La. ... '30
Bremner, Carl St. J., 2320 State St., Santa Barbara, Calif. ... '23
||Brewer, Charles, Jr., 1 D Gibson Terrace, Cambridge, Mass. ... '27
||Brian, J. Carl, Aspermont, Tex. ... '28
Brice, John W., Standard Oil Co. of Venezuela, Caripito, Venezuela, S. A. ... '28
Bridge, Josiah, Room 337, U. S. National Museum, Washington, D. C. ... '28
||Briggs, Robert C., Jr., 207 Plaza Apt. Hotel, Houston, Tex. ... '32
Brill, Virgil A., Box 938, McCamey, Tex. ... '33

Brillhart, Norman W., Box 654, Madill, Okla. '28
||Brinkerhoff, Ira A., 1129 S. Thirty-Fifth Ave., Omaha, Neb. '29
Briscoe, Glenn O., General Delivery, Holden, Mo. '22
||Broadhurst, William L., Box 342, Gruver, Tex. '31
||Brock, Stephen W., 3050 R St., Lincoln, Neb. '30
Brockway, E. R., 407 N. Seventh St., Marshall, Ill. '24
Brokaw, Albert D., Parsonage Hill Road, Short Hills, N. J. '22
||Brooks, Olin D., 5807 Prospect Ave., Dallas, Tex. '30
Broomfield, R. A., Jr., 912 Petroleum Securities Bldg., Los Angeles, Calif. '28
||Broun, L. Coleman, Box 239, Southport, Conn. (Mail returned) '31
||Brown, Arthur B., Box 1390, Station C, Los Angeles, Calif. '31
Brown, E. Call, 4445 Gainsborough Ave., Los Angeles, Calif. '23
Brown, Harry J., 640 W. Fourteenth St., Tulsa, Okla. '25
Brown, Ira Otho, 1423 Milam Bldg., San Antonio, Tex. '24
Brown, J. Earle, 1305 Madeline Place, Fort Worth, Tex. '20
Brown, J. Marshall, Lago Petr. Corp., Bella Vista, Maracaibo, Venezuela, S. A. '25
Brown, James Chapman, Blairfordel, 31 Balgreen Road, Edinburgh, Scotland '27
||Brown, Louis N., Amarillo Gas Co., Amarillo, Tex. '31
||Brown, Merritt H., Darby Petr. Corp., 507 Philcade Bldg., Tulsa, Okla. '29
||Brown, Otto E., 1828 N. Park St., Shawnee, Okla. '31
Brown, Prentice F., Box 776, Midland, Tex. '29
Brown, Robert, 1601 N. Kickapoo, Shawnee, Okla. '30
Brown, Robert Wesley, St. Lawrence University, Geological Dept., Canton, N. Y. '20
Brown, Samuel B., Ford, Bacon & Davis, Inc., 39 Broadway, New York, N. Y. '29
Brown, Vergil N., 2603 N. Robinson, Oklahoma City, Okla. '23
||Brown, William F., 304 S. Main St., Mt. Pleasant, Mich. '30
Browning, Iley B., Box 126, Ashland, Ky. '21
Bruce, George H., 1005 Union Natl. Bank Bldg., Wichita, Kan. '25
Brucks, E. W., 354 Cavalier Ave., San Antonio, Tex. '24
||Brunner, Michael C., 433 Higgins Bldg., Los Angeles, Calif. '29
Bruyere, Alan, Box 983, Fort Worth, Tex. '19
Bryan, Frank, Box 188, Waco, Tex. '19
Bryant, Howard S., Skelly Oil Co., Ellis Singleton Bldg., Wichita, Kan. '27
Bryant, John O., 2545 E. Sixth St., Tulsa, Okla. '27
Buchanan, George S., Barnsdall Oil Co., Petroleum Bldg., Tulsa, Okla. '25
Buchner, Carl F., 2101 Missouri Pacific Bldg., 1226 Olive St., St. Louis, Mo. '26
Buck, E. O., Box 1428, Amarillo, Tex. '27
Buckstaff, Sherwood, 412 N. Franklin, Anthony, Kan. '27
Buddenhagen, H. J., 392 S. Coronado, Ventura, Calif. '31
Buehler, H. A., Rolla, Mo. '21
Bullard, Edgar F., Box 591, Tulsa, Okla. '23
Bullard, Fred M., Univ. of Texas, Geological Dept., Austin, Tex. '20
Bunn, John R., 604 Simpson Bldg., Ardmore, Okla. '26
Bunte, Arnold S., Shell Petr. Corp., Iowa, La. '26
Burchfiel, Hugh L., Box 973, Midland, Tex. '23
Burford, Selwyn O., 1133 Weaver St., Houston, Tex. '26
||Burger, Robert W., 1338 N. Columbus Ave., Glendale, Calif. '30
Burling, Lancaster D., 5041 Lydia Ave., Kansas City, Mo. '24
Burnett, Jerome B., Lago Petr. Corp., Apartado 172, Maracaibo, Venezuela, S. A. '18
||Burnett, T. J., Box 598, Tyler, Tex. '30
Burnham, Roderick D., 3129 Durand Drive, Los Angeles, Calif. '27
Burress, Walter M., Box 727, Tyler, Tex. '20
||Burslem, John, c/o Miss Austin, Euphan, Flackwell Heath, High Wycombe, Bucks, England '30
Burt, Frederick A., A. and M. College, College Station, Tex. '32
Burt, Roy A., Fifty-Sixth & Shawnee Mission Road, Kansas City, Kan. '20
Burton, George E., 4349 Southern Ave., Dallas, Tex. '17
||Burton, Waldo E., Mountain Park, Okla. '30
Burtt, John G., 428 Higgins Bldg., Los Angeles, Calif. '19
Bush, Frederic A., 2145 N. Elwood, Tulsa, Okla. '31
Butcher, Cary P., Box 311, San Angelo, Tex. '24
Butler, Frank H., Sun Oil Co., Warren, Tex. '28
Butt, William H., Apartado 10, Matanzas, Cuba '32

Buttermore, Paul M., 3061 Wabash St., Fort Worth, Tex. '27
Butters, Roy M., 36 Sherman St., Denver, Colo. '21
Butterworth, E. M., Ned. Pac. Petr. Mij., Batavia, Java, D. E. I. '21
Buttram, Frank, 2909 First Natl. Bank Bldg., Oklahoma City, Okla. '18
Buttram, William A., Route 2, Puente, Calif. '22
Buwalda, John P., California Inst. of Technology, Pasadena, Calif. '26
Buzzo, Thomas W., Box 807, Tyler, Tex. '23
||Byars, Roy W., Box 115, Stroud, Okla. '29
Bybee, Hal P., 805 San Angelo Natl. Bank. Bldg., San Angelo, Tex. '19
||Bynum, Charles G., Nederland, Colo. '27
||Byram, Ronald W., Box 1618, University Station, Austin, Tex. '24
Byrd, David Harold, 1108 Tower Petroleum Bldg., Dallas, Tex. '27

Cadle, Austin, Room 1523, Standard Oil Bldg., San Francisco, Calif. '25
||Cadman, A. Denys, N-13 Lowell House, Cambridge, Mass. '31
Callahan, Drury V., c/o Westheimer & Daube, Ardmore, Okla. '26
||Calohan, William F., 1706 Market St., Laredo, Tex. '31
Camp, Richard W., Box 1439, Oklahoma City, Okla. '30
Campbell, Ian, California Inst. of Technology, Geological Dept., Pasadena, Calif. '26
||Campbell, John M., Box 278, Laredo, Tex. '31
Campbell, Keir A., 2544 Hyde St., San Francisco, Calif. '32
Campbell, Robert B., Box 1265, San Antonio, Tex. '23
Cannon, Joe, 505 San Angelo Natl. Bank Bldg., San Angelo, Tex. '28
Cannon, R. L., 505 San Angelo Natl. Bank Bldg., San Angelo, Tex. '23
||Cardwell, D. Harold, Box 236, Gladewater, Tex. '30
Carlson, Charles G., Peerless Oil & Gas Co., 702 Natl. Bank of Commerce Bldg., Tulsa, Okla. '24
Carlson, Edwin N., 612 Bitting Bldg., Box 552, Wichita, Kan. '24
Carlton, Dave P., Humble Oil Co., 901 Humble Bldg., Houston, Tex. '20
Carney, Frank, Box 397, B. U. Station, Waco, Tex. '21
Carpenter, Everett, 2214 Ong St., Amarillo, Tex. '21
Carpenter, Marble J., 703 Masonic Bldg., Bartlesville, Okla. '22
||Carpenter, Margaret C., 1305 E. Magnolia, Fort Worth, Tex. '27
Carpenter, M. E., 342 Key Bldg., Oklahoma City, Okla. '25
||Carr, George W., Shell Petr. Corp., Geophysical Dept., Box 2099, Houston, Tex. '26
||Carrell, Olleon, Godley, Tex. '28
Carsey, J. Ben, Box 938, McCamey, Tex. '26
Carson, Carlton M., Box 101, Cupertino, Santa Clara County, Calif. '27
||Carson, R. E. L., 2910 Fannin, Houston, Tex. '30
||Carter, Devere V., Box 1238, Kilgore, Tex. '28
Carter, Frank B., 601 Bankers Bldg., 629 S. Hill St., Los Angeles, Calif. '26
Cartwright, Lon D., Jr., San Jacinto Life Bldg., Beaumont, Tex. '24
Case, Leslie C., Box 661, Tulsa, Okla. '26
Case, William B., Shell Petr. Corp., Drawer 8, St. Louis, Mo. '22
||Cash, Thornton C., Humble Oil & Refg. Co., Tyler, Tex. '23
Cashin, D'Arcy M., 3403 Yoakam Blvd., Houston, Tex. '19
Cassel, Chester, 5328 Abbott Place, Los Angeles, Calif. '30
Cassingham, Robert L., 506 American Natl. Bank Bldg., Enid, Okla. '27
Casteel, S. H., Box 1519, Fort Worth, Tex. '30
Caudill, Samuel J., 1504 Philtower Bldg., Tulsa, Okla. '19
Cave, Harold S., Box 2097, Denver, Colo. '23
Cavins, O. A., 225 Bush St., San Francisco, Calif. '21
||Cesinger, E. F., 405 S. Waverly Drive, Dallas, Tex. '27
||Champion, Oscar R., 726 E. Moses, Cushing, Okla. '30
Chapin, Theodore, Aberdeen, Wash. '23
Chapman, Guy E., Southern Crude Oil Purch. Co., 1704 Milam Bldg., San Antonio, Tex. '28
Chappuis, Louis, 2931 E. Hope St., Huntington Park, Calif. '27
Charles, Homer H., Drawer L, Bartlesville, Okla. '25
Charlton, Frances, Univ. of California, Dept. of Paleontology, Berkeley, Calif. '32
Charrin, P., 30 Rue Fabert, Paris, VII, France '28
Chase, James L., 2425 California Ave., Long Beach, Calif. '22
Chawner, William Donald, Apartado 10, Matanzas, Cuba '29

Cheney, Charles A., 717 Ritz Bldg., Tulsa, Okla. '20
Cheney, M. G., Coleman, Tex. '19
Cheney, Robert B., Box 660, Tyler, Tex. '28
Chevalier, Jerome A., 510 Exchange Bank Bldg., Tulsa, Okla. '25
Cheyney, Alvin E., 536 S. Lorraine, Witchita, Kan. '21
Childerhose, Allen J., Texas Co. of Canada, Langman Bldg., Calgary, Alta., Canada '30
Chisholm, William F., 2511 Highland Ave., Shreveport, La. '27
‖Christensen, H. E., Box 2420, Tulsa, Okla. '29
‖Christian, Walton, 519 N. Morton St., Okmulgee, Okla. '30
Christie, Laurence G., Shell Petr. Corp., Box 2099, Houston, Tex. '25
‖Christie, Robert S., Amerada Petr. Corp., Route 6, Longview, Tex. '25
Christner, D. D., 2121 Mistletoe Ave., Fort Worth, Tex. '24
‖Christner, J. B., Box 232, Rockdale, Tex. '28
‖Church, Charles R., Jr., 217 W. Walnut St., Titusville, Pa. '31
Church, Clifford C., 79 New Montgomery St., San Francisco, Calif. '30
Clapp, F. G., 49 Warwick Road, Lawrence Park, West, Bronxville, N. Y. '18
Clark, Bruce L., Univ. of California, Hearst Mining Bldg., Berkeley, Calif. '27
Clark, Chester C., 524 Kirby Place, Shreveport, La. '19
Clark, Clare M., 1531 S. Twenty-Fifth St., Lincoln, Neb. '28
Clark, Clifton W., 719 City Natl. Bank Bldg., Wichita Falls, Tex. '19
Clark, Frank Rinker, Box 981, Tulsa, Okla. '20
‖Clark, G. Conrad, Megargel, Tex. '31
Clark, Glenn C., Continental Oil Co., Ponca City, Okla. '19
Clark, Howard, Reserve Petr. Co., Philcade Bldg., Tulsa, Okla. '23
Clark, H. Smith, Box 767, Fort Worth, Tex. '22
‖Clark, John W., Box 971, Oklahoma City, Okla. '27
Clark, Joseph M., Box 661, Tulsa, Okla. '29
Clark, Leslie M., Box 442, Santa Maria, Calif. (Mail returned) '26
Clark, L. W., 1719 Milam Bldg., San Antonio, Tex. '29
Clark, Robert P., 816 Second Natl. Bank Bldg., Houston, Tex. '27
Clark, Robert W., 2236 Almont St., Carrick, Pittsburgh, Pa. '18
Clark, Stuart K., Continental Oil Co., Ponca City, Okla. '19
Clark, W. C., 1007 Second Ave., Council Bluffs, Iowa '29
Clark, William A., Jr., Box 24, Livingston, Tex. '26
Clark, William L., 803 S. Jenkins, Norman, Okla. '25
Classen, Willard J., Associated Oil Co., Room 435, 79 New Montgomery St., San Francisco, Calif. '23
Clawson, William W., 2321 N. Youngs Blvd., Oklahoma City, Okla. '25
‖Clay, Withers, 519 Third Ave., Hibbing, Minn. '26
‖Claypool, C. B., Attica, Ind. '30
Clifford, O. C., Jr., Seismograph Service Corp., 906 Cosden Bldg., Tulsa, Okla. '28
Clifton, R. L., Box 1123, Enid, Okla. '25
Cline, Justus H., Stuarts Draft, Va. '20
Clinkscales, Albert S., 804 Colcord Bldg., Oklahoma City, Okla. '19
Clopton, John H., 1601 Milam Bldg., San Antonio, Tex. '30
Closuit, E. M., 703 Browder St., Dallas, Tex. '22
Clowe, Charles E., Box 417, Ardmore, Okla. '23
Cloyes, S. B., 4120 S. Main, Houston, Tex. '27
‖Coates, George H., Plaza Hotel, San Antonio, Tex. '26
Cobb, Margaret C., 124 E. Eighty-Fourth St., New York, N. Y. '26
Cochran, Phil K., Carter Oil Co., 810 Central Bldg., Wichita, Kan. '23
Coffin, R. Clare, Stanolind Oil & Gas Co., Tulsa, Okla. '26
‖Coil, Fay, 764 Jenkins St., Norman, Okla. '30
‖Coke, John M., 4730 Tennyson St., Denver, Colo. '28
Cole, Edwin G., Sinclair Oil & Gas Co., Enid, Okla. '25
Cole, Virgil B., Box 143, Perry, Okla. '24
Cole, W. Storrs, 1692 Wyandotte Road, Columbus, Ohio '27
Coleman, Bond, Mound City, Kan. '25
Coleman, Don P., 3223 E. English, Wichita, Kan. '32
Coleman, Tom L., Box 1074, Wichita Falls, Tex. '24
Collingwood, D. M., Sun Oil Co., Box 807, Tyler, Tex. '21
Collins, C. Philip, 702 S. Second St., McAlester, Okla. '25
Collins, Melvin J., 339 Milam Bldg., San Antonio, Tex. '24

||Collins, Wallace H., 1846 E. Seventeenth St., Tulsa, Okla. .... '22
Collom, Roy E., Continental Oil Co., Ponca City, Okla. .... '19
||Colman, I. C., 512 S. Seventeenth St., Columbus, Ohio .... '30
Colton, Earl G., Okmulgee, Okla. .... '29
Comstock, William S., 512 Union Oil Bldg., Los Angeles, Calif. .... '28
Condit, D. Dale, 2160 Prosser Ave., West Los Angeles, Calif. .... '21
Conkling, R. A., 804 Colcord Bldg., Oklahoma City, Okla. .... '17
Conkling, Russell C., Shell Petr. Corp., Box 620, San Angelo, Tex. .... '22
Conkling, William H., 1524 Shafter St., San Angelo, Tex. .... '22
||Conners, Thomas P., 414 Bellefontaine, Kansas City, Mo. .... '30
||Conrad, Charles S., Esperson Bldg., Houston, Tex. .... '29
Cook, Carroll E., 506 W. Twenty-Second St., Austin, Tex. .... '22
Cook, Harold J., Agate, Neb. .... '20
Cooper, Chalmer L., 326 Nine and One-half St., Parkersburg, W. Va. .... '26
Cooper, Herschel H., 1624 Milam Bldg., San Antonio, Tex. .... '25
Copass, Jack M., 1601 S. Jenkins, Norman, Okla. .... '27
Copeland, Richard G., 1212 S. Broadway, Tyler, Tex. .... '27
Copelin, Leonard S., 607 Richfield Oil Bldg., Los Angeles, Calif. .... '30
Corbett, Clifton S., Gulf Oil Co., 17 Battery Place, New York, N. Y. .... '19
Corby, Grant W., Box 514, Arcadia, Los Angeles County, Calif. .... '26
||Cordry, C. D., Box 737, Fort Worth, Tex. .... '29
||Corey, William Henry, 810 Gaviota, Long Beach, Calif. .... '32
||Cornell, Lee H., 413 First Natl. Bank Bldg., Wichita, Kan. .... '27
||Corning, Leavitt, Jr., 6202 Howe St., Pittsburgh, Pa. (Mail returned) .... '30
Cortes, Henry C., Magnolia Petr. Co., Box 872, Lake Charles, La. .... '30
Coryell, Horace N., Columbia University, New York, N. Y. .... '26
Coryell, Lewis S., 339 W. Fifth St., Bristow, Okla. .... '20
||Coryn, F. R., Drawer F., Houston, Tex. .... '30
Cotner, Victor, Box 1141, Amarillo, Tex. .... '27
Cottingham, Virgil E., Box 474, San Angelo, Tex. .... '21
Cotulla, Louis E., Box 235, Albany, Tex. .... '26
Cotulla, Reuben E., 614 Denver Blvd., San Antonio, Tex. .... '26
||Coulson, Harry S., 513 N. W. Fourth Ave., Mineral Wells, Tex. .... '28
||Courtier, William H., Kinsley, Kan. .... '28
Cox, Benjamin Burton, c/o C. Stuart Morgan, Room 417, 26 Broadway, New York, N. Y. .... '26
Cox, Thomas S., Box 589, Beeville, Tex. .... '28
||Craft, Benjamin C., Louisiana State University, Baton Rouge, La. .... '30
Craig, Eric K., 1234 Ethel St., Glendale, Calif. .... '28
||Craig, T. C., Phillips Petr. Co., Amarillo, Tex. .... '31
Cram, Ira H., 1729 S. Cincinnati, Tulsa, Okla. .... '26
Cramer, Louis W., Stockton Hotel, Fort Stockton, Tex. .... '27
Crandall, Hector, Anadarko-Western-Oil Co., 2002 Philtower Bldg., Tulsa, Okla. .. '24
Crandall, Kenneth H., Box 971, Alice, Tex. .... '23
Crandall, Richard R., 945 Schumacher Drive, Los Angeles, Calif. .... '24
Crandall, Roderic, 17 Battery Place, New York, N. Y. .... '24
Cranson, Lorin A., 215 Market St., San Francisco, Calif. .... '29
Crawford, David J., 3251 Culver St., Dallas, Tex. .... '27
Crebbs, Chester M., Apartado 234, Maracaibo, Venezuela, S. A. .... '22
Crider, Albert F., 821 Ontario St., Shreveport, La. .... '22
||Crider, Hugh D., 431 Lyman Bldg., Muskegon, Mich. .... '28
||Crist, Raymond E., 3533 Vista Ave., Cincinnati, Ohio .... '30
Croneis, Carey, Walker Museum, Univ. of Chicago, Chicago, Ill. .... '29
Crook, Theo H., c/o W. B. Thomas, 6699 Telegraph Ave., Oakland, Calif. .... '24
||Crosby, Arthur S., 4213 Clinton, Los Angeles, Calif. .... '28
||Crotty, James W., Box 217, Safford, Ariz. .... '27
Crouse, George T., Shell Petr. Corp., Houston, Tex. (Mail returned) .... '27
Crum, Harry E., Columbian Carbon Co., Charleston, W. Va. .... '23
Cruse, John S., Jr., Pure Oil Co., 2213 Esperson Bldg., Houston, Tex. .... '26
Cullen, Ronald J., Twin State Oil Co., Box 1501, Tulsa, Okla. .... '23
Culver, Harold E., State College of Washington, Pullman, Wash. .... '24
Cumming, Alfred, Route 1, Box 11-A, Bixby, Okla. .... '24
Cunningham, Carleton J., Box 548, Laredo, Tex. .... '29

Cunningham, George M., 2610 Nineteenth St., Bakersfield, Calif. '24
Curry, William H., Jr., 1118 City Central Bank Bldg., San Antonio, Tex. '28
Curtice, A. Arthur, 435 A. G. Bartlett Bldg., 215 W. Seventh St., Los Angeles, Calif. '24
||Cushing, John W., Sistersville, W. Va. '30
Cushman, Joseph A., 76 Brook Road, Sharon, Mass. '24
Cutler, Willard W., Jr., 1729 N. Canyon Drive, Los Angeles, Calif. '17
Cuyler, Robert H., 1216 W. Twenty-Second St., Austin, Tex. '29

||Dahlgren, Elmer George, 2617 N. Hudson St., Oklahoma City, Okla. '32
Dake, Charles L., 1106 Main St., Rolla, Mo. '27
Dakin, Francis W., 1134 Hinman Ave., Evanston, Ill. '23
Dallmus, Karl F., Cia. de Petr. Mercedes S. A., Apartado 269, Monterrey, N. L., Mexico '28
Dally, Claude F., 4120 Mattison, Fort Worth, Tex. '20
Damon, Gordon, Box 1609, University Station, Austin, Tex. '29
Dana, Drexler, 3106 Lauro Canyon Road, Santa Barbara, Calif. '27
||Dana, Edward B., Box 143, Belpre, Ohio '26
Dana, P. L., 725 S. Chestnut St., Kewanee, Ill. '30
Daniels, Harold G., 219 E. Rosewood, San Antonio, Tex. '21
Daniels, James I., Continental Oil Co., Ponca City, Okla. '24
Dannenberg, R. M., Comar Oil Co., Marland, Okla. '25
Dannettell, Merle Q., 906 E. Tenth St., Pueblo, Colo. '24
Danvers, Don, 1715 Milam Bldg., San Antonio, Tex. (Mail returned) '26
Darke, Roy E., 2004 Truxtun, Bakersfield, Calif. '27
Darnell, James L., Room 1951, 420 Lexington Ave., New York, N. Y. '22
||Darnell, James L., Jr., 420 Lexington Ave., New York, N. Y. '28
||Dashti, Abdullah Khan, c/o Ali Dashti, Teheran, Persia '33
||Daszynski, Stephen W., 28 Lancaster Road, London, N. W. 3, England '28
Davies, Fred A., The California Co., Tower Petroleum Bldg., Dallas, Tex. '20
Davies, Herman F., 306 Conoco Bldg., Denver, Colo. '27
||Davies, Nathan C., 133 W. Gray St., Elmira, N. Y. '29
Davies, Stanley J., 1128 Prospect Ave., Calgary, Alta., Canada '31
||Davis, Charles A., Estimating Div., Arizona State Highway Dept., Phoenix, Ariz. '27
Davis, Donald M., Pure Oil Co., Houston, Tex. '26
Davis, Elmer Fred, Shell Oil Co., 431 Higgins Bldg., Los Angeles, Calif. '21
||Davis, Fenelon F., 585 Thirty-Sixth St., Oakland, Calif. '29
||Davis, Field M., 904 Wilkinson St., Shreveport, La. '31
Davis, Morgan J., Ned. Kol. Petr. Mij., Batavia, Java, D. E. I. '26
Davis, Ralph E., 1710 Union Bank Bldg., Pittsburgh, Pa. '19
Davis, Robert J., Shell Petr. Corp., Drawer 8, St. Louis, Mo. '21
Davis, Thornton, Simms Oil Co., 2302 Alamo Natl. Bldg., San Antonio, Tex. '25
||Dawson, Edwin A., The Texas Co., Box 1801, Wichita, Kan. '30
Dawson, Joseph M., 735 Milam Bldg., San Antonio, Tex. '23
Dawson, William A., 1229½ W. Thirty-Eighth St., Oklahoma City, Okla. '26
Day, Clarence O., Phillips Petr. Co., 708 Slattery Bldg., Shreveport, La. '20
||Day, James R., Box 1223, Students Exchange, College Station, Tex. '30
Day, Willard L., 1223 Aganier, San Antonio, Tex. '26
Dean, D. P., 1816 W. T. Wagonner Bldg., Fort Worth, Tex. '19
Dean, P. C., 1816 W. T. Wagonner Bldg., Fort Worth, Tex. '19
De Chicchis, Romaldo, Southern Crude Oil Purch. Co., Midland, Tex. '29
Decius, L. Courtney, Associated Oil Co., 79 New Montgomery St., San Francisco, Calif. '19
de Cizancourt, Henry, Compagnie française des Petroles, 9 square Messine, Paris VIII, France '29
*Decker, Charles E., 508 Chautauqua Ave., Norman, Okla. '17
||Decker, LaVerne, Marshall Hotel, Marshall, Tex. '27
de Cousser, Kurt H., 201 Dean Apts., 727 N. Capitol Ave., Lansing, Mich. '27
De Ford, Ronald K., Box 81, Golden, Colo. '25
De Golyer, E., 120 Broadway, Suite 2703, New York, N. Y. '17
||Delehanty, R. V., 92 Liberty St., New York, N. Y. '31
||Delo, David M., Northwestern University, Geological Dept., Evanston, Ill. '29

de Loys, Francis, 63 St. James St., London, S. W. 1, England..................'21
Denison, A. R., Box 1348, Fort Worth, Tex..................................'21
Denman, C. E., 209 S. Ninth St., Enid, Okla.................................'26
Denning, Wayne H., 921 Nineteenth St., Golden, Colo.........................'28
||Deputy, P. R., The Texas Co., Room 1003, 929 S. Broadway, Los Angeles, Calif...'30
Deussen, Alexander, 1606 Post Dispatch Bldg., Houston, Tex..................'17
DeWolf, Frank W., Univ. of Illinois, Geological Dept., Urbana, Ill..............'20
Dicken, Russell H., 909 Ash Ave., Duncan, Okla..............................'28
Dickerson, Roy E., Apartado 10, Matanzas, Cuba..............................'25
||Dietert, Arthur E., Box 326, Richmond, Ky..................................'31
Dille, Glenn Scott, Box 912, Tulsa, Okla......................................'28
||Dinsmoor, Carlton G., Moran, Tex...'32
Disney, Orville A., General Delivery, Sedan, Kan..............................'20
Dissinger, Earl, 1915 E. Alabama Ave., Houston, Tex..........................'20
Dixon, A. Faison, 37 Clifford Ave., Pelhamwood, N. Y..........................'19
Doane, George H., Room 604, 1709 W. Eighth St., Los Angeles, Calif.............'26
Dobbin, Carroll E., 523 Custom House, Denver, Colo............................'22
Dobie, Walter L., Box 773, El Dorado, Ark.....................................'26
Dodge, John F., Univ. of California, Division of Petr. Engineering, Los Angeles, Calif...'24
Dodson, Floyd C., 208 S. Park St., San Angelo, Tex.............................'23
Doering, John, 1401 Tower Petroleum Bldg., Dallas, Tex.........................'30
||Dolphin, Adrian J., Box 154, Owensboro, Ky...................................'20
Donahue, Frank, 402 S. Fourth St., Ponca City, Okla............................'25
||Donnelly, Alden Stuart, Box 776, Midland, Tex................................'30
Donoghue, David, 1116 Fort Worth Natl. Bank Bldg., Fort Worth, Tex..........'18
Donovan, Percy W., 1701 Foshay Tower, Minneapolis, Minn.......................'19
Dorchester, Charles M., Gulf Refg. Co., Box 1731, Shreveport, La...............'19
Dorr, James B., Huasteca Petr. Co., Apartado 94, Tampico, Mexico..............'25
Dorrance, James R., 18 Flower St., Bakersfield, Calif..........................'26
Dorsey, Geo. Edwin, Box 904, Dallas, Tex......................................'24
Dott, Robert H., 1521 S. Yorktown, Tulsa, Okla................................'18
Douglas, James M., 1108½ Brent St., S. Pasadena, Calif.........................'23
Douglas, John G., Box 606, Chapel Hill, N. C...................................'27
||Douglas, L. A., 1641 W. Huisache, San Antonio, Tex............................'30
||Douglass, O. Hubert, Jr., 2832 W. Seventeenth St., Oklahoma City, Okla. (Mail returned)...'27
Dovre, Adolph, 128 E. Magnolia Ave., San Antonio, Tex.........................'22
Downing, Roswell B., 607 Union Natl. Bank Bldg., Wichita, Kan.................'30
Doyle, John J., Humble Oil & Refg. Co., Box 233, Lake Charles, La..............'24
||Dragusanu, J. B., Columbia Gas & Elec. Corp., 800 Union Trust Bldg., Pittsburgh, Pa...'29
Drake, Cecil, Apartado 150, Tampico, Mexico....................................'29
||Drake, Lemuel Clyde, Box 1024, Memphis, Tex...................................'31
Dreher, Otto, Ferdinandstrasse 27, Hannover, Germany..........................'21
||Dresbach, C. H., 512 Greendale Ave., Edgewood, Pittsburgh, Pa.................'31
Dresser, Myron A., Box 171, Elk City, Okla.....................................'19
Driver, Herschel L., 630 W. Palm Drive, Glendale, Calif........................'25
Duce, James Terry, The Texas Co., 135 E. Forty-Sceond St., New York, N. Y.....'20
||Duce, Robert S., 1153 Lincoln St., Boulder, Colo...............................'30
Dufour, Jan, Caribbean Petr. Corp., Maracaibo, Venezuela, S. A.................'30
Dugan, Ira E., 301 S. Lake, Ponca City, Okla...................................'24
Dunlevy, Robert B., 302 College St., Winfield, Kan.............................'21
Dunn, George V., 2035 E. Fourteenth St., Tulsa, Okla...........................'22
||Dunn, Jack W., Hudson's Bay Oil & Gas Co., 516 Lougheed Bldg., Calgary, Alta., Canada..'31
Durkee, Robert R., Dixie Oil Co., 1704 Milam Bldg., San Antonio, Tex..........'28
Durward, R. H., 710 W. Rosewood, San Antonio, Tex..............................'26
Duston, Arthur W., 415 Philtower Bldg., Tulsa, Okla............................'21

Eagles, Homer M., Room 1060, 26 Broadway, New York, N. Y......................'22
Earl, Will F., 822 Coolidge Ave., Wichita, Kan..................................'25
Eastman, Walter F., 9 Locust Ave., Danbury, Conn...............................'26

Easton, H. D., Suite 309, Slattery Bldg., Shreveport, La. ... '17
Eaton, Joseph E., 4546 Tujunga Ave., N. Hollywood, Calif. ... '25
Eby, J. Brian, Box 962, Houston, Tex. ... '25
||Eckenwiler, Cleo W., 507 Philcade Bldg., Tulsa, Okla. ... '32
Eckert, Frank E., c/o Hanley & Bird, Bradford, Pa. ... '21
Eckhardt, E. A., 1520 Shady Ave., Pittsburgh, Pa. ... '30
Edson, Dwight J., Box 101, San Angelo, Tex. ... '22
Edson, Fanny C., Shell Petr. Corp., Box 1191, Tulsa, Okla. ... '22
Edwards, Everett C., 501 Coast Blvd. South, Laguna Beach, Calif. ... '23
||Edwards, Hall, 740 Philcade Bldg., Tulsa, Okla. ... '28
Edwards, Merwin G., Shell Oil Co., 430 Higgins Bldg., Los Angeles, Calif. ... '25
Egan, John A., 502 Thompson Bldg., Tulsa, Okla. (Mail returned) ... '23
||Eichelberger, John R., 754 S. Grove St., Wichita, Kan. (Mail returned) ... '30
Eichelberger, Orion H., 606 Pujo St., Lake Charles, La. ... '23
Eirich, Constance G., Box 661, Tulsa, Okla. ... '21
||Ekholm, Victor E., 610 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. ... '28
Elin, Nicolas D., State Oil Trust "Grozneft," Grotzny, U.S.S.R. ... '31
Elledge, Emmett R., Phillips Petr. Co., Breckenridge, Tex. ... '25
||Ellicott, F. M., Apt. 3, 824 Blaylock Drive, Dallas, Tex. ... '30
Elliott, George R., Petroleum & Natural Gas Div., 119 Sixth Avenue, West, Calgary, Alta., Canada ... '26
Elliott, John E., 4731 E. Fifty-Second Drive, Los Angeles, Calif. ... '19
Ellis, George L., 436 S. Forty-Ninth St., Philadelphia, Pa. ... '24
Ellison, Charles W., 1201 N. Broadway, Shawnee, Okla. ... '30
Ellison, Kenneth A., 1315 N. Payne, Oklahoma City, Okla. ... '28
Ellisor, Alva C., 903 Humble Bldg., Houston, Tex. ... '21
Elson, William H., 306 Beacon Life Bldg., Tulsa, Okla. ... '27
Ely, Fred B., 122 E. Forty-Second St., New York, N. Y. ... '20
Emch, John W., Box 452, San Angelo, Tex. ... '25
Emendorfer, Earl, 6649 Monroe St., Hammond, Ind. ... '27
Emery, Wilson B., 1041 S. Center St., Casper, Wyo. ... '23
Emmons, William H., Univ. of Minnesota, Minneapolis, Minn. ... '19
Emrick, D. G., Drawer C, Houston, Tex. ... '28
Emrick, E. Byers, Box 496, Conrad, Mont. ... '22
Engel, Rene L. H., California Inst. of Technology, Geological Dept., Pasadena, Calif. ... '25
Engleman, Rolf, Apartado 10, Matanzas, Cuba ... '25
English, Leon E., 806 Euclid Ave., Lawton, Okla. ... '18
English, Walter A., 601 W. Fifth St., Room 930, Los Angeles, Calif. ... '19
Erb, Josef T., van Dorpstr. 9, The Hague, Holland ... '24
Erdmann, Charles E., 523 Custom House, Denver, Colo. ... '30
Erni, Arthur, Landhaus Kully, Trimbach, Kt. Solothurn, Switzerland ... '21
||Erwin, Andrew V., 818 Kennedy Bldg., Tulsa, Okla. ... '21
Esary, Ralph E., 925 Hunter Ave., Bloomington, Ind. ... '32
Esgen, W. K., Humble Oil & Refg. Co., Houston, Tex. ... '29
||Eskrigge, Tatham R., Box 1214, Pittsburgh, Pa. ... '30
Estabrook, Edward L., Standard Oil Co. of N. J., 26 Broadway, New York, N. Y. ... '20
Estergren, E. F., 1011 Sixth Ave., Fort Worth, Tex. ... '29
||Evans, Eugene P., Drawer 2040, Tulsa, Okla. ... '30
Evans, Frank G., Jr., Box 386, Teague, Tex. ... '28
||Evans, Louis H., 226 Bartlett Bldg., Seventh & Spring St., Los Angeles, Calif. ... '24
Eyoub, Djevad, 302 Furr Drive, San Antonio, Tex. ... '26
Eyssell, Alfred R., 1105 Alamo Natl. Bldg., San Antonio, Tex. ... '25

Fagin, Verne A., 538 E. Cincinnati, San Antonio, Tex. ... '27
||Fahmy, E. H., No. 5 Bateniah St., El Azhar, Cairo, Egypt ... '26
Farish, Linn M., Foreign Dept., Henry L. Doherty & Co., 60 Wall St., New York, N. Y. ... '28
||Farrell, Agnes M., 706 Harvard Hall, 1650 Harvard St., N. W., Washington, D. C. '26
Fash, Ralph H., Box 1008, Fort Worth, Tex. ... '27
Fath, A. E., Semperhaus B/III, Hamburg 1, Germany ... '17
||Faulkner, Hastings M., 606 E. Xyler, Tulsa, Okla. ... '30
||Faust, Joseph, 1215 N. Hudson, Oklahoma City, Okla. ... '31

Faust, L. Y., Box 2040, Tulsa, Okla. .... '32
||Feagin, Barney, Jr., 330 Ritz Bldg., Tulsa, Okla. .... '30
Fenn, Ivan J., Box 172, Lordsburg, N. Mexico .... '29
Fergus, Preston, 400 Forsythe, Monroe, La. .... '27
||Ferguson, Glenn C., 604 Beaux Arts Bldg., 1708 W. Eighth St., Los Angeles, Calif. .'30
Ferguson, John L., Drawer 2040, Tulsa, Okla. .... '20
Ferguson, Kenneth S., Box 894, Carlsbad, N. Mexico .... '27
Ferguson, R. N., 547 Subway Terminal Bldg., 417 S. Hill St., Los Angeles, Calif. .. '19
||Ferguson, William Boyd, Box 553, Brenham, Tex. .... '29
||Ferrero, Clarence, Gramercy, La. .... '28
Fettke, Charles R., 1118 Wightman St., Pittsburgh, Pa. .... '20
||Field, R. H., c/o D. D. Field, R. D. 1, Santa Ana, Calif. .... '30
||Field, Walter S., 421 Ellis Singleton Bldg., Wichita, Kan. (Mail returned) .... '28
||Fields, Harry B., Box 73, Marion, N. Dakota .... '28
Finch, Elmer H., c/o L. S. Tubbs, 311 W. Mistletoe, San Antonio, Tex. .... '22
Finch, John Wellington, Univ. of Idaho, Bureau of Mines & Geology, Moscow, Idaho .... '24
||Fipps, E. L., 509 W. Sixteenth St., Joplin, Mo. .... '26
Fischer, Otto, Box 1375, Charleston, W. Va. .... '17
Fisher, D. J., Univ. of Chicago, Rosenwald Hall, Chicago, Ill. .... '27
Fisher, Leslie A., Box 5, Conroe, Tex. .... '31
||Fitts, John, 910 E. Seventeenth St., Ada, Okla. .... '27
Fitzgerald, James, Jr., Skelly Oil Co., Tulsa, Okla. .... '25
||Fitzgerald, Paul E., 221 S. Mission St., Mt. Pleasant, Mich. .... '30
Flagler, C. W., Apartado 234, Maracaibo, Venezuela, S. A. .... '30
Floyd, Florin W., 108 E. Twenty-Sixth St., Tulsa, Okla. .... '23
||Fly, Paul J., 715 W. Pine St., Hattiesburg, Miss. .... '31
Fohs, F. Julius, 51 E. Forty-Second St., New York, N. Y. .... '17
Foley, Lyndon L., Box 981, Tulsa, Okla. .... '22
Folger, Anthony, Gypsy Oil Co., 1107 Union Natl. Bank Bldg., Wichita, Kan. .... '22
||Fonville, Herman Albert, 1515 Ninth St., Wichita Falls, Tex. .... '27
Foran, William T., St. Maries, Idaho .... '31
Ford, Carl S., 601 E. B. & T. Bldg., Enid, Okla. .... '18
Forgeron, H. S., 1422½ Stratford Ave., S. Pasadena, Calif. .... '28
Forgotson, James M., 925 W. New York Ave., Albuquerque, N. Mexico .... '29
Forrester, George A., 251 S. Rutan, Wichita, Kan. .... '20
Fortier, Leo R., Drawer 1400, Wichita, Kan. .... '25
Fortine, Dwight H., 536 W. One Hundred and Twelfth St., Los Angeles, Calif. ... '30
Fosdick, Arthur R., 706 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. .... '32
Fossa-Mancini, Enrico, Direccion General Y. P. F., Paseo Colon 922, Buenos Aires, Argentina, S. A. .... '31
Foster, Fred E., 940 Roosevelt Bldg., Los Angeles, Calif. .... '28
Foster, F. K., 506 N. Avenue K, Muskogee, Okla. (Mail returned) .... '21
Fowler, Charles W., Jr., 334 Milam Bldg., San Antonio, Tex. .... '26
Fowler, George M., 314 Joplin Natl. Bank Bldg., Joplin, Mo. .... '23
||Fox, Ira William, 701 Oakland Ave., Greensburg, Pa. .... '27
||Fox, James P., Apartado 4, Puerto Mexico, Ver., Mexico .... '29
Fox, Leo S., General Petr. Corp., 1003 Higgins Bldg., Los Angeles, Calif. .... '27
||Francis, George A., Box 274, Coffeyville, Kan. .... '26
Franklin, Louis, 547 Harvey-Snider Bldg., Wichita Falls, Tex. .... '20
||Franks, Robert M., 904 Milam Bldg., San Antonio, Tex. .... '30
Freedman, L. H., 1402 Sinclair Bldg., Fort Worth, Tex. .... '22
Frei, Frederick, 2003 Tower Petroleum Bldg., Dallas, Tex. .... '25
||Freie, A. J., Standard Oil Co. of Venezuela, Box 284, Port of Spain, Trinidad, B. W. I. .... '28
Frey, Alfred P., Caribbean Petr. Co., Maracaibo, Venezuela, S. A. .... '24
Fritts, Harold M., Box 868, San Angelo, Tex. .... '26
||Fritz, Earl R., 1803 East Ave., Austin, Tex. .... '30
Froyd, Erwin A., Midwest, Wyo. .... '22
Fuellhart, Donald E., Natchitoches, La. .... '29
||Fulton, Loris J., 921 S. Eighth St., Chickasha, Okla. .... '29
||Funk, Fred J., Box 1079, Casper, Wyo. .... '28
Funk, Marion H., Box 741, Gladewater, Tex. .... '24

Fuqua, H. B., Box 737, Fort Worth, Tex. .... '20
Fyfe, Douglas, 215 W. Seventh St., Los Angeles, Calif. .... '20

Gaddess, Jack, North Pennsylvania Gas Co., Port Allegany, Pa. .... '25
Gahring, William Ross, Box 520, Shawnee, Okla. .... '25
Galbraith, T. J., Jr., 1943 W. Gramercy, San Antonio, Tex. .... '20
||Gale, Hoyt Rodney, Box 238, Helena, Mont. .... '29
Galloway, J. J., Univ. of Indiana, Geological Dept., Bloomington, Ind. .... '25
Galloway, John O., Box 750, Coalinga, Calif. .... '21
Galpin, Sidney L., West Virginia University, Geological Dept., Morgantown, W. Va. .... '19
||Gardner, A. Maclay, 502 N. Washington Ave., Whittier, Calif. .... '30
Gardner, James H., 326 Beacon Life Bldg., Tulsa, Okla. .... '17
Gardner, Julia, U. S. Geological Survey, Washington, D. C. .... '27
||Gardner, William I., 515 Delaware St. S. E., Minneapolis, Minn. .... '31
Garfias, Valentine R., Henry L. Doherty & Co., 60 Wall St., New York, N. Y. .... '19
Garlough, J. L., 331 N. Fountain Ave., Wichita, Kan. .... '28
Garner, Aubrey H., 256 S. Mountain Ave., Montclair, N. J. .... '19
||Garner, John W., 395 N. E. Sixteenth St., Portland, Ore. .... '28
Garnjost, Frederick W., Spuyten Duyvil, New York, N. Y. .... '21
Garrett, Lovic P., 4301 Rossmoyne Blvd., Houston, Tex. .... '18
Garrett, Melvin M., 801 Hamilton Bldg., Wichita Falls, Tex. (Mail returned) .... '21
Garrett, Robert E., 533 Beacon Life Bldg., Tulsa, Okla. .... '21
Garrett, S. G., Mansfield, Pa. .... '20
||Garst, Jarvis, Apartado 209, Monterrey, N. L., Mexico .... '31
Gartner, James L., Box 1765, Tulsa, Okla. .... '19
Gauthier, Charles B., E. A. Parkford Co., 408 Pacific Mutual Bldg., Los Angeles, Calif. (Mail returned) .... '29
Gaylord, E. G., 225 Bush St., San Francisco, Calif. .... '20
Gealy, Wendell B., 3306 Iowa St., Pittsburgh, Pa. .... '26
Geis, Wilfrid H., 910 Ocean Center Bldg., Long Beach, Calif. .... '23
Gella, Norbert A., Kohlenstrasse 417, Kassel-Wilhelmshoehe, Germany .... '31
George, W. O., 606 Eighth Ave., Laurel, Miss. .... '24
Germany, E. B., 3301 Beverly Drive, Dallas, Tex. .... '26
Gester, George C., 1129 Standard Oil Bldg., San Francisco, Calif. .... '20
Gester, Stephen H., 1128 Standard Oil Bldg., San Francisco, Calif. .... '21
Getzendaner, A. E., 831 Nixon Bldg., Corpus Christi, Tex. .... '24
Getzendaner, Frank M., Uvalde, Tex. .... '21
Gevaerts, E. A. L., Mauritskade 6, The Hague, Holland .... '28
||Gibbs, Harley S., 416 Zara St., Pittsburgh (10), Pa. .... '30
Gibbs, James F., Panhandle Refg. Co., Box 1107, Wichita Falls, Tex. .... '27
||Gibson, W. C., Jr., Box 145, Wellington, Kan. .... '29
Giddings, Harvard, 149 Seventh St., Fond du Lac, Wis. .... '26
Gierhart, Guy B., Box 548, Laredo, Tex. .... '28
Giffin, Wilson C., 1003 Higgins Bldg., Los Angeles, Calif. .... '19
Gilbert, A. C., Jr., El Reno, Okla. .... '28
||Gilbert, J. Sterling, Box 75, Lamont, Okla. .... '31
||Gilboe, John D., 1614 Richland Place, Bakersfield, Calif. .... '26
||Gile, Richard E., 3136 Irving Ave. S., Minneapolis, Minn. .... '29
Giles, Albert W., Univ. of Arkansas, Geological Dept., Fayetteville, Ark. .... '22
Giles, John M., 5367 Wingohocking Terrace, Germantown, Pa. .... '26
Gillan, Silas L., 230 Webb Drive, Glendale, Calif. .... '26
Gillespie, Bartlett W., 108 S. El Molino, Alhambra, Calif. .... '27
Gillson, Joseph L., 8060 Du Pont Bldg., Wilmington, Del. .... '30
Gilmour, Andrew, Drawer 2040, Tulsa, Okla. .... '29
Gish, Wesley G., Sinclair-Prairie Oil Co., Box 767, Fort Worth, Tex. .... '22
Glenn, L. C., 2111 Garland Ave., Nashville, Tenn. .... '19
Goblot, Henri, 3 Rue Andrieux, Paris, France .... '29
Goldston, Walter L., Jr., 718 Esperson Bldg., Houston, Tex. .... '20
Goldstone, Frank, Shell Petr. Corp., Box 2099, Houston, Tex. .... '30
Goodman, A. J., 50 Cleveley Crescent, Priory Park, Hanger Lane, Ealing, W. 5, London, England .... '30
Goodman, P. W., Box 188, Cement, Okla. .... '31

*Goodrich, Harold B., 1628 S. Cincinnati, Tulsa, Okla. '18
||Goodrich, Paul K., 1540 Garfield, Brownsville, Tex. '30
Goodrich, Raymond H., 2117 Gulf Bldg., Houston, Tex. '24
Goodrich, Robert D., 706 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. '18
||Goodwill, Donald, Jr., 503 E. & W. St., Minden, La. '31
Goodwin, Guy L., 850 Subway Terminal Bldg., 417 S. Hill St., Los Angeles, Calif. '27
Gordon, Dugald, 521 Slattery Bldg., Shreveport, La. '22
Gordon, Wallace, 502 Oklahoma Savings Bldg., Oklahoma City, Okla. '20
Goubkin, I. M., Leontievsky per. 25 Kw. 14, Twerskaya, Moscow, U.S.S.R. '32
Goudkoff, Paul P., 1204 Subway Terminal Bldg., Los Angeles, Calif. '25
Gouin, Frank, Box 72, Duncan, Okla. '19
Gould, Charles N., Oklahoma Geological Survey, Norman, Okla. '17
||Gould, Don B., Cornell College, Geological Dept., Mount Vernon, Iowa '28
Gow, Kenneth L., 548 Subway Terminal Bldg., Los Angeles, Calif. '31
||Grage, Victor P., 301 S. Holyoke, Wichita, Kan. '30
||Graham, B. L., Empire Oil & Refg. Co., Masonic-Empire Bldg., Bartlesville, Okla. '29
Graham, William A. P., Ohio State University, Geological Dept., Columbus, Ohio '29
Graham, W. L., Route 2, Orlando, Okla. '29
Grant, Paul A., Columbus, Mont. '23
||Grant, U. S., IV, Univ. of California, Geological Dept., Los Angeles, Calif. '32
Gray, Alfred, 4112 Gaston Ave., Dallas, Tex. '20
Gray, Allan B., Fierro, N. Mexico '28
Gray, Shapleigh G., The Texas Co., Box 1737, Shreveport, La. '28
Gray, William D., Box 2168, Tulsa, Okla. '27
||Gregory, J. N., Box 273, San Angelo, Tex. '30
Green, Darsie A., 320 E. Keith St., Norman, Okla. '25
Green, Guy E., 710 W. Russell Place, San Antonio, Tex. '24
Greene, Frank C., 1434 S. Cincinnati, Tulsa, Okla. '17
Greene, Ray G., Route 1, Box 531, San Jose, Calif. '20
Greenwood, Chester L., 3905 Clayton Ave., Los Angeles, Calif. '31
Greig, Douglas A., c/o Thos. Cook & Son (Bankers), Ltd., Head Office, Berkeley St., Piccadilly, London, W. 1, England '30
Gretzinger, William, 5743 Aylesboro Ave., Pittsburgh, Pa. '20
Griffith, Cunningham L., Venezuela Gulf Oil Co., Apartado 234, Maracaibo, Venezuela, S. A. '22
Griffith, Glenn R. V., 400 Fair Oak St., Little Valley, N. Y. '28
Grigsby, Garland O., 1836 Irving Place, Shreveport, La. '28
Grigsby, R. B., Stanolind Oil & Gas Co., Box 87, Shreveport, La. '24
Griley, Horace L., Twin State Oil Co., Box 1348, Tulsa, Okla. '24
Grim, Ralph E., 804 S. First St., Champaign, Ill. '27
Grimes, Glenn, Wirt Franklin Petr. Corp., 703 Franklin Bldg., Oklahoma City, Okla. '29
Grimes, Russell W., Shell Petr. Corp., Geological Dept., St. Louis, Mo. '27
||Grimm, George A., Stroud, Okla. '27
Grimm, Maurice W., 203 Ward Bldg., Shreveport, La. '25
Grinsfelder, Sam, Box 1122, Beeville, Tex. '24
Griswold, Clyde T., 1500 Las Lomas Road, Albuquerque, N. Mexico '18
Grogan, Samuel A., Apartado 106, Tampico, Mexico '24
||Gross, Arthur B., Ramsey Petr. Corp., Petroleum Bldg., Oklahoma City, Okla. '28
||Gude, Leo J., 1005 Tradesmen's Bank Bldg., Oklahoma City, Okla. '30
||Guerrero, Alberto Lobo-, Apartado 666, Bogota, Colombia, S. A. '31
Guinn, Delmar R., Empire Gas & Fuel Co., Roswell, N. Mexico '29
Gulley, M. Gordon, c/o K. C. Heald, Box 1214, Pittsburgh, Pa. '25
Gunby, Merle F., Box 1014, Houston, Tex. '24
||Gunn, James E., 116 W. Kaufman St., Paris, Tex. '33
Gunter, Herman, 715 E. Virginia St., Tallahassee, Fla. '21
Gutenberg, Beno, Seismological Laboratory, 220 N. San Rafael Ave., Pasadena, Calif. '31
Gutzwiller, Otto, Bremgarten, Aargau, Switzerland '28

||Haas, Carl J., General Delivery, Overton, Tex. '29
||Haas, Johann Otto, 75 Route de Lyon, Illkirch, Bas-Rhin, France '31
Hafner, W., Ferdinandstr. 27, Hannover, Germany '26
Hagan, Arthur M., Box 1456, Corpus Christi, Tex. '25

Hagan, E. F., Morgantown, W. Va. '27
Hageman, Donald E., 525 Clark Ave., Billings, Mont. '23
||Hagen, Cecil Vernon, Box 674, Laredo, Tex. '31
Hager, Dilworth S., 515 Milam Bldg., San Antonio, Tex. '22
Hager, Dorsey, Hotel Morck, Aberdeen, Wash. '19
Hager, Lee, 1521 Esperson Bldg., Houston, Tex. '18
Hagy, Lawrence R., 508 Amarillo Bldg., Amarillo, Tex. '25
||Hahn, Raymond R., Barnes, Warren County, Pa. '23
Haigh, Berte R., College of Mines, El Paso, Tex. '31
Haight, Harold W., Box 823, McAllen, Tex. '27
Hake, Benjamin F., 515 Lougheed Bldg., Calgary, Alta., Canada '26
||Halbouty, Michel T., Yount-Lee Oil Co., Beaumont, Tex. '31
Hall, Ellis A., Box 211, Abilene, Tex. '25
Hall, Elwin B., 640 Title Insurance Bldg., Los Angeles, Calif. '24
Hall, Roy H., 270 S. Dellrose, Wichita, Kan. '18
Halse, G. W., British Controlled Oilfields, Ltd., Siparia P. O., Palo Seco, Trinidad, B. W. I. '28
||Halsted, Morris E., Guthrie, Okla. '30
Hamill, James M., Box 1640, Station C, Los Angeles, Calif. '29
||Hamilton, C. E., 401 W. Tonhawa, Norman, Okla. '28
Hamilton, Charles W., 17 Battery Place, 16th Floor, New York, N. Y. '20
Hamilton, W. R., Box 1466, Tulsa, Okla. '18
Hamm, W. Dow, Shell Petr. Corp., Box 2099, Houston, Tex. '22
||Hamman, John, Jr., 2006 Gulf Bldg., Houston, Tex. '30
Hammer, Alva A., 2231 Idlewild, Abilene, Tex. '21
Hammill, Chester A., 1417 First Natl. Bank Bldg., Dallas, Tex. '17
||Hammond, Weldon W., Box 1238, Kilgore, Tex. '31
||Hancock, Bob, 121 North D St., Yale, Okla. '30
Hancock, J. M., United Production Corp., Geological Dept., Beeville, Tex. '31
||Hancock, Ray A., R. D. 1, Box 462, Fullerton, Calif. '30
||Hancock, William T., Jr., 406 Marshall St., Houston, Tex. '30
Hanna, G. Dallas, California Academy of Sciences, San Francisco, Calif. '24
Hanna, Marcus A., 2910 Arbor, Houston, Tex. '25
Hanson, Edwin V., Box 1756, Houston, Tex. '26
Hanson, Perry R., Box 2033, Wichita, Kan. '27
||Hard, Edward W., 257 Bryant St., Buffalo, N. Y. '30
||Hardin, E. Glenn, 318 E. Fifteenth St., Oklahoma City, Okla. '20
Hardison, George P., Shell Petr. Corp., Box 1191, Tulsa, Okla. '32
Hardy, Norman, Ned. Pac. Petr. Mij., Batavia, Java, D. E. I. '27
Hares, C. J., 305 Franklin St., Denver, Colo. '23
Harkness, R. B., Whitney Block, Parliament Bldgs., Toronto, Ont., Canada '24
Harlowe, Leslie S., Louisiana Oil Refg. Co., Box 1117, Shreveport, La. (Mail returned) '21
Harlton, Bruce H., Amerada Petr. Corp., Drawer 2040, Tulsa, Okla. '27
Harnsberger, T. K., Sophian Plaza, Tulsa, Okla. '19
Harper, Oliver C., 2020 W. One Hundred Second St., Chicago, Ill. '21
||Harrell, David C., 3115 Speedway, Austin, Tex. '29
Harrell, Marshall A., R. R. 5, Bloomington, Ind. '27
Harrington, George L., F. C. C. N. A., Kilom. 1391, A. Vespucio, Provincia De Salta., Argentina, S. A. '24
Harrington, Rollin B., Box 848, Huntington, W. Va. '21
||Harris, Edwin S., 307 N. Main St., Henderson, Tex. '27
Harris, Richard C., Union Natl. Petr. Co., Apartado 484, Caracas, Venezuela, S. A. '25
||Harris, R. W., Box 856, Norman, Okla. '26
Harrison, John Vernon, 34 Rowallan Gardens, Glasgow, W. 1, Scotland '31
Harrison, Thomas S., Box 324, Encinitas, Calif. '19
||Harriss, T. Fairman, 225 Federal Bldg., Honolulu, Hawaii '29
Hartley, Burton, 343 E. Craig Place, San Antonio, Tex. '17
Hartman, Adolph E., 909 Milam Bldg., San Antonio, Tex. '17
Harvey, William W., 1022 Milam Bldg., San Antonio, Tex. '26
Haseltine, Raymond H., Box 2880, Dallas, Tex. '27
Hasselmann, Karl F., 1912 Esperson Bldg., Houston, Tex. '26
Hatcher, Oscar, Box 91, Seminole, Okla. '27

||Hatfield, Arlo C., Box S. S., Breckenridge, Tex. '31
Haury, P. S., Drawer G, Smackover, Ark. '23
Hawkins, Arthur L., Route 8, Box 241, San Antonio, Tex. (Mail returned) '28
Hawkins, Glenn D., Drawer I, Duncan, Okla. '28
Hawley, Henry J., 225 Bush St., San Francisco, Calif. '24
Haworth, Huntsman, 815 Bitting Bldg., Wichita, Kan. '17
||Hawtof, E. Manuel, Box 715, Waco, Tex. '26
Hay, Lawrence C., 4329 E. English, Wichita, Kan. '21
Hayes, Albert O., Rutgers University, New Brunswick, N. J. '21
Hayes, Reese L., Box 11, Olney, Tex. '18
Haynes, Winthrop P., 68 Pall Mall, London, S. W. 1, England '17
||Hayward, Landes H., 534 North Ave. 53, Los Angeles, Calif. '31
Hazzard, Andrew M., 440 Atlantic Ave., Long Beach, Calif. '27
Hazzard, Roy T., Gulf Refg. Co. of Louisiana, Shreveport, La. '25
Headley, Joseph B., Box 781, Roswell, N. Mexico '25
Heald, K. C., The Gulf Companies, Gulf Bldg., Pittsburgh, Pa. '17
Heater, W. E., 825 S. McClelland, Santa Maria, Calif. '31
Heath, Francis E., 5442 Monticello St., Dallas, Tex. '24
||Heaton, Adrian H., 314 W. Second St., Carthage, Mo. '30
Heaton, R. L., 2374 Elm St., Denver, Colo. '20
Hedberg, Hollis D., Venezuela Gulf Oil Co., Apartado 234, Maracaibo, Venezuela, S. A. '26
||Hedges, K. P., 614 S. Elwood, Apt. B-7, Tulsa, Okla. '29
Hedley, J. David, Barnsdall Oil Co., 2212 Esperson Bldg., Houston, Tex. '25
Hedrick, O. F., Texas Pacific Coal & Oil Co., Thurber, Tex. '23
Hegwein, Walter H., Cia. Mex. Pet. "El Aguila," Apartado 150, Tampico, Mexico '30
Heid, Gordon W., Ned. Kol. Petr. Mij., Weltevreden, Java, D. E. I. '27
Heidecke, Otto, Bakenstr. 2, Halberstadt, Germany '29
Heidenreich, W. Lee, 216 Seventeenth St., Santa Monica, Calif. '21
Heiland, Carl A., Colorado School of Mines, Golden, Colo. '28
Helquist, G. A., Luteranskiy per N. 3, Baku, U.S.S.R. '31
Hemmings, H., Caribbean Petr. Co., Maracaibo, Venezuela, S. A. '27
||Hemphill, Herbert A., 2 N. Bishop, San Angelo, Tex. '31
Hemphill, Joe C., Vacuum Oil Co., Box 1292, Midland, Tex. '27
Henbest, Lloyd G., Room 327, U. S. National Museum, Washington, D. C. '31
Henderson, Charles W., 519 Custom House Bldg., Denver, Colo. '25
Henderson H. H., 1935 W. Magnolia. San Antonio, Tex. '24
||Henderson, William David, Dixie Oil Co., Geological Dept., Shawnee, Okla. '29
Hendrickson, Victor J., 1703 Williams St., Denver, Colo. '23
||Heninger, Dan D., 1934 E. Houston St., San Antonio, Tex. '29
Henley, A. S., 1752 Kenneth Road, Glendale, Calif. '18
Hennen, Ray V., Monongahela Bldg., Morgantown, W. Va. '19
Henniger, Waldemar F., 3355 Del Monte Drive, Houston, Tex. '18
Henning, John L., 525 Kirby St., Lake Charles, La. '19
Henny, Gerard, 1031 S. Broadway, Los Angeles, Calif. '23
Henry, Leonard W., Apartado 93, Maracaibo, Venezuela, S. A. '30
Henry, Schuyler, B., The Bahrein Petr. Co., Ltd., Bahrein Island, Persian Gulf, via Baghdad '25
Henson, F. R. S., P. O. Box 61, Baghdad, Iraq '32
Henson, G. R., Shell Petr. Corp., Shell Bldg., St. Louis, Mo. '24
Herald, Frank A., 2105 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. '21
Herald, John M., 605 Cosden Bldg., Tulsa, Okla. '17
||Herndon, Harold D., Box 417, Tyler, Tex. '29
Herold, Stanley C., 756 S. Broadway, Los Angeles, Calif. '19
Heroy, William B., 39 Wayne Ave., White Plains, N. Y. '22
Herrick, Henry N., 1300 Standard Oil Bldg., San Francisco, Calif. '27
||Herring, Frank, 805 E. Williams St., Breckenridge, Tex. '29
Herring, L. B., 207 W. Whaley, Longview, Tex. (Mail returned) '29
Hertel, Francis W., Box R, Ventura, Calif. '25
Heusser, Hans, Conde Penalver 15, Madrid, Spain '31
||Hickey, Harold N., 816 First Natl. Bank Bldg., Great Falls, Mont. '24
||Hicks, Ira M., Box 832, San Angelo, Tex. '31
Hiestand, Thomas C., W. C. McBride, Inc., 508 Wright Bldg., Tulsa, Okla. '25

Higgs, Morton T., Sun Oil Co., Box 2880, Dallas, Tex. '24
Hill, Harry B., 551 Federal Bldg., Dallas, Tex. '26
*Hill, Robert T., Hotel Commodore, Los Angeles, Calif. '19
Hill, V. G., Stanolind Oil & Gas Co., Box 814, Enid, Okla. '28
Hillis, Donuil, 728 S. New Hampshire St., Los Angeles, Calif. '26
Hindes, E. P., Henry L. Doherty & Co., 60 Wall St., New York, N. Y. '17
Hinds, Henry, Room 2749, 420 Lexington Ave., New York, N. Y. '19
||Hlauschek, Hans, Nabr. legii 10, Prague, 16, Czechoslovakia '30
||Hobson, Henry David, Continental Oil Co., 417 S. Hill St., Los Angeles, Calif. '30
Hockman, James N., c/o G. P. Halsted, Guthrie, Okla. '24
Hodge, Edwin T., 1825 Fairmont St., Eugene, Ore. '20
Hodson, Floyd, Standard Oil Co. of Venezuela, Caripito, Venezuela, via Trinidad, B. W. I. '25
||Hodson, Helen K., Standard Oil Co. of Venezuela, Caripito, Venezuela, via Trinidad, B. W. I. '27
Hoekstra, Jean A., Bataafsche Petr. Mij., Batavia, D. E. I. '27
||Hoenshell, David T., Box 120, Coalinga, Calif. '26
Hoffman, Charles C., 705 New Masonic Bldg., Bartlesville, Okla. '20
Hoffman, Malvin G., Box 5, Pullman, Wash. '21
Hoffmann, Charles R., 79 Grandes Arcades, Strasbourg, Alsace, France '27
Hoffmeister, William S., Lago Petr. Corp., Apartado 172, Maracaibo, Venezuela, S. A. '28
Hogan, Dana, University Club, Los Angeles, Calif. '27
||Hoke, T. C., 611 Osage, Bartlesville, Okla. '29
Holden, Roy J., Polytechnic Institute, Blacksburg, Va. '25
Holl, Frederick G., 4004 E. Kellogg, Wichita, Kan. '21
||Holland, Arthur J., Box 56, Kings Mill, Tex. '30
Holland, Laurier F. S., Bin F, Placerville, Calif. '27
||Hollingsworth, R. V., 447 College, Norman, Okla. '32
Holloman, Roy, c/o Max W. Ball, 425 First Natl. Bank Bldg., Denver, Colo. '21
Holman, Eugene, Room 1512, 26 Broadway, New York, N. Y. '20
Holman, W. H., 1415 S. Gramercy Place, Los Angeles, Calif. '27
Holmes, S. W., Box 312, Shawnee, Okla. '28
||Homer, George W., 1410 W. Lynwood Ave., San Antonio, Tex. '30
Honess, Charles W., 2215 N. Broadway, Shawnee, Okla. '17
Hood, Forrest W., 444 Chautauqua, Norman, Okla. '28
||Hook, James H., 2609 Waits Ave., Fort Worth, Tex. '29
||Hookway, L. C., 810 N. Michigan Ave., Pasadena, Calif. '30
Hoots, Harold W., Union Oil Co. of California, 1113 Union Oil Bldg., Los Angeles, Calif. '21
||Hoover, F. Mabry, Empire Oil & Refg. Co., Box 1163, Oklahoma City, Okla. '27
||Hoover, James B., 439 S. Hillside, Wichita, Kan. '29
Hoover, James E., 608 Natl. Bank of Commerce Bldg., Tulsa, Okla. '19
Hoover, J. Wilkinson, The California Co., Smith-Young Tower, San Antonio, Tex. '28
Hoover, William B., Box 668, Pampa, Tex. '25
Hopkins, Edwin B., 1307 First Natl. Bank Bldg., Dallas, Tex. '18
Hopkins, James, 157 S. Catalina St., Los Angeles, Calif. '29
Hopkins, Oliver B., Imperial Oil Co., 56 Church St., Toronto, Ont., Canada '21
Hopper, Walter E., Box 1280, Shreveport, La. '20
Horkey, William E., 1915 S. Wheeling St., Tulsa, Okla. '27
||Hornberger, Joseph, Jr., 2420 Arbor, Houston, Tex. '30
Horton, Leo V., New Chickasha Hotel, Chickasha, Okla. '29
Horton, Harold M., 1104 Tower Petroleum Bldg., Dallas, Tex. '26
Hoskins, Baker, Jr., Box 291, Beeville, Tex. '26
Hosterman, John F., Box 832, San Angelo, Tex. '25
Hotchkin, Harry, Wells Hotel, Tulsa, Okla. '24
Hotz, Walter, Mineralogisches Institut, Bernoullianum, Basle, Switzerland '26
Housh, C. N., Gulf Prod. Co., Box 311, Longview, Tex. '24
||Houston, Sam H., Jr., 2015 Smith-Young Tower, San Antonio, Tex. '31
Howard, Arthur Henry, St. Helen's Court, Leadenhall St., London, E. C. 3, England '24
||Howard, Dan O., 209 E. Thirteenth St., Oklahoma City, Okla. '28
Howard, William M., Box 374, Dixon, Calif. '29

Howard, W. V., Univ. of Illinois, Geological Dept., Urbana, Ill. . . . . '29
Howe, Henry V., Louisiana State University, Geological Dept., Baton Rouge, La. '23
Howell, J. V., 300 N. Fourth St., Ponca City, Okla. . . . . '17
Howell, William F., 1015 Guilford Ave., Greensboro, N. C. . . . . '21
||Howendobler, John L., 1104 S. Lawton, Tulsa, Okla. . . . . '21
Howeth, Irving K., Box 1125, Beeville, Tex. . . . . '26
Hoyle, Charles R., 201 W. Franklin, Shawnee, Okla. . . . . '23
Hoyt, William V., 440 Argo Ave., San Antonio, Tex. . . . . '21
||Hruby, Milton, 217 N. Park Ave., Buffalo, N. Y. . . . . '30
||Hubbard, Allen F., Box 579, Long Beach, Calif. . . . . '29
Hubbard, Bela, Carter Oil Co., Box 801, Tulsa, Okla. . . . . '27
Hubbard, William E., Humble Oil & Refg. Co., McCamey, Tex. . . . . '19
Hubbert, M. K., Columbia University, Geological Dept., New York, N. Y. . . . . '28
||Hubman, Carl W., Box 15, Boulder, Colo. . . . . '29
||Huddleston, Arthur N., 3903 Montrose Blvd., Houston, Tex. . . . . '28
Hudnall, James S., Box 740, Tyler, Tex. . . . . '27
Hudson, Frank S., 1625 Opechee Way, Glendale, Calif. . . . . '23
Hudson, William A., 1810 Electric Bldg., Fort Worth, Tex. . . . . '26
Hughes, C. Don, 1901 Van Buren St., Amarillo, Tex. . . . . '21
Hughes, Richard, Box 268, Tulsa, Okla. . . . . '19
||Hughes, Richard V., Johns Hopkins University, Geological Dept., Baltimore, Md. . . . . '30
Hughes, Urban B., Eastman, Gardner & Co., Laurel, Miss. . . . . '20
Hughes, V. H., 601 Exchange Natl. Bank Bldg., Tulsa, Okla. . . . . '18
Hulin, Carlton D., 1711 Central Ave., Alameda, Calif. . . . . '25
Hull, J. P. D., 2506 N. Cheyenne Ave., Tulsa, Okla. . . . . '20
Hume, George S., Geological Survey of Canada, Ottawa, Ont., Canada . . . . '27
Hummel, E. W., c/o W. G. Hummel, Mountain View, Okla. . . . . '18
Hummel, H. L., 1621 W. Magnolia, San Antonio, Tex. . . . . '23
Hunt, Edwin H., The Texas Co. of Canada, Ltd., Calgary, Alta., Canada . . . . '24
Hunt, Raymond S., Box 149, Mount Pleasant, Mich. . . . . '25
Hunter, Campbell M., 4 London Wall Bldgs., London, E. C. 2, England . . . . '27
Hunter, Coleman D., 608 Second Natl. Bank Bldg., Ashland, Ky. . . . . '30
Hunter, Dresden B., 245 N. Oliver St., Wichita, Kan. . . . . '25
Hunter, Harry M., 1419 Ninth St. West, Calgary, Alta., Canada . . . . '28
Hunter, James W., Box 696, McAllen, Tex. . . . . '27
Hunter, Paul B., Box 1865, Houston, Tex. . . . . '24
||Hunter, R. E. L., 1221 N. E. Euclid, Oklahoma City, Okla. . . . . '31
Huntley, Louis G., 2811 Grant Bldg., Pittsburgh, Pa. . . . . '19
Hupp, John Ervin, c/o L. B. O'Neil, Cut Bank, Mont. . . . . '26
Hurndall, John P., 334 N. Normandie Ave., Los Angeles, Calif. (Mail returned) . . . . '25
Hutcheson, R. Bellenden, 2022 W. Seventy-Fourth St., Los Angeles, Calif. . . . . '28
Hutchinson, Frederick M., 410 Avondale Ave., Houston, Tex. . . . . '24
Hutchison, L. L., 625 Exchange Natl. Bank Bldg., Tulsa, Okla. . . . . '19
Hutson, E. B., Standard Oil Co., Geological Dept., Shreveport, La. . . . . '24
Hyde, Clarence E., 3628 Watonga Ave., Fort Worth, Tex. . . . . '23
Hynes, Dibrell P., 80 E. Jackson, Chicago, Ill. . . . . '24

Ickes, E. L., 10463 Tennessee Ave., West Los Angeles, Calif. . . . . '24
Iddings, Arthur, International Petr. Co., Ltd., Talara, Peru, S. A. . . . . '19
Iki, Tsunenaka, Imperial University of Tokyo, Mining Dept., Tokyo, Japan . . . . '24
Ilsley, Ralph, 1200 Massachusetts Ave., 24 E., Cambridge, Mass. . . . . '27
Imbt, Robert F., 1520 Paseo de Vaca, San Angelo, Tex. . . . . '23
||Imbt, William C., 324 Braeside Ave., E. Stroudsburg, Pa. . . . . '31
||Ingham, W. I., Hartman, Colo. . . . . '28
Irwin, J. S., 3026 Glencoe Road, Calgary, Alta., Canada . . . . '19
||Irwin, Wallace W., Box 127, Midland, Tex. . . . . '30
Isenberger, Nate P., 118 N. Monroe St., San Angelo, Tex. . . . . '25
Israelsky, Merle C., United Gas Corp., Box 2492, Houston, Tex. . . . . '25
Ivy, John Smith, United Gas Corp., Houston, Tex. . . . . '25

Jablonski, Eugene, Vacuum Oil Co., Inc., 26 Broadway, New York, N. Y. . . . . '27
Jackson, C. L., 909 College Ave., Midland, Tex. . . . . '29

James, Wright E., 505 Cornell St., Palo Alto, Calif. ... '25
Jay, Stanley E., 721 W. Ferguson, Tyler, Tex. ... '24
‖Jeffrey, H. C., Sinclair Oil & Gas Co., San Angelo, Tex. (Mail returned) ... '29
Jeffreys, Geoffrey, 80 Maiden Lane, New York, N. Y. ... '26
Jenkins, J. H., Associated Oil Co., 79 New Montgomery St., San Francisco, Calif. '24
Jenkins, Olaf P., 630 Amherst St., Palo Alto, Calif. ... '28
Jennings, Charles I., Salmar Oil Corp., 805 E. Elm St., Seguin, Tex. ... '24
Jenny, W. P., 44 Pestalozzistr., Berne, Switzerland ... '26
Jensen, Joseph, 766 Pacific Electric Bldg., Los Angeles, Calif. ... '23
‖Joekel, Fred E., 350 Cedar Springs Road, Dallas, Tex. ... '29
Johnson, Carlyle D., 401 Continental Oil Bldg., Denver, Colo. ... '31
Johnson, E. L., 2311 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. ... '29
‖Johnson, George V., 1300 Standard Oil Bldg., San Francisco, Calif. ... '30
Johnson, Harry R., 838 Roosevelt Bldg., Los Angeles, Calif. ... '23
‖Johnson, Henry L., U. S. Engineers, Rock Island, Ill. ... '30
Johnson, J. Harlan, Box 336, Golden, Colo. ... '24
Johnson, Roswell H., 1039 Murrayhill Ave., Pittsburgh, Pa. ... '19
Johnson, Russell V., 960 Jervis St., Vancouver, B. C., Canada ... '20
‖Johnston, Esther S., 1643 S. Broadway, Boulder, Colo. ... '28
‖Johnston, Graham, c/o Norwood Johnston, 1081 Shady Ave., Pittsburgh, Pa. ... '30
Johnston, Kenneth A., 1643 S. Broadway, Boulder, Colo. ... '28
‖Jolley, Durward N., 215 Ward Bldg., Shreveport, La. ... '31
‖Jones, A. L., Coleman, Okla. ... '27
Jones, Alva V., Merry Bros. & Perini, Box 482, Paducah, Tex. (Mail returned) ... '27
Jones, B. Delbert, 419 Sherman Bldg., Corpus Christi, Tex. (Mail returned) ... '29
Jones, Boone, 300 S. Mississippi, Ada, Okla. ... '21
‖Jones, Charles T., 412 W. Adams Ave., McAlester, Okla. ... '29
Jones, Coy B., 126 Club Drive, San Antonio, Tex. ... '24
Jones, Daniel J., Box 485, Lexington, Ky. ... '28
Jones, David Glynn, Compania Terrocarrilera de Petroleo, Km. 8, Comodoro Rivadavia, R. Argentina, S. A. ... '30
Jones, Edward L., Jr., Box 802, Phoenix, Ariz. ... '22
Jones, James J., 328 N. Xenophon, Tulsa, Okla. ... '21
‖Jones, Jess R., Box 5, Lookeba, Okla. ... '30
Jones, Ogden S., Texoma Natural Gas Co., 4th Floor Rule Bldg., Amarillo, Tex. ... '29
Jones, Richard A., 1011 San Pedro Ave., San Antonio, Tex. (Mail returned) ... '23
Jones, Robert L., Empire Gas & Fuel Co., Tyler, Tex. ... '25
Jones, Roy D., 812 E. Sixteenth St., Oklahoma City, Okla. ... '23
Judson, Sidney A., 3783 Carlon St., Houston, Tex. ... '24
Jung, Jean, 2 rue Boussaingault, Strasbourg, France ... '29
‖Junger, Arne, Box 55, Wasco, Calif. ... '30
Just, Evan, New Mexico School of Mines, Socorro, N. Mexico ... '23
Justice, Philip S., Sun Oil Co., Drawer 790, Beaumont, Tex. ... '22

Kamb, Hugo R., 2215 Russell Ave., N., Minneapolis, Minn. ... '27
Kane, William G., Apartado 134, Saltillo, Coahuila, Mexico ... '26
Karcher, John C., 4004 Euclid Ave., Dallas, Tex. ... '31
Kaselitz, Fritz, Bornhausen am., Harz, Germany ... '30
Kauenhowen, Walter, Deutsche Vacuum Oel A. G., Semperhaus B. III, Hamburg, Germany ... '28
‖Kauffman, James S., 105 E. Haskell Place, Tulsa, Okla. ... '30
‖Kauffman, William E., The Texas Co., Box 999, Wichita Falls, Tex. ... '30
Kaufmann, Godfrey, Huasteca Petr. Co., Apartado 94, Tampico, Tamps., Mexico ... '25
Kautz, Archie R., Box 2404, Amarillo, Tex. ... '20
Kay, Fred H., Pan American Petr. & Transport Co., 122 E. Forty-Second St., New York, N. Y. ... '19
Kay, G. Marshall, Columbia University, Geological Dept., New York, N. Y. ... '29
Kay, John A., Shasta Oil Co., Box 661, Longview, Tex. ... '29
Keeler, Clifton M., 408 N. W. Thirty-Third St., Oklahoma City, Okla. ... '19
Keeler, Edgar A., 716 S. Guthrie, Tulsa, Okla. ... '30
Keeler, William W., 701 Atlas Life Bldg., Tulsa, Okla. ... '24
Keen, C. D., 529 Robinson Place, Shreveport, La. ... '32
Keenan, J. Kenneth, 1135 Hunt Bldg., Tulsa, Okla. ... '22

Kehrer, L., B. P. M., Tjepoe, Java, D. E. I. '30
||Keim, Roy E., 3019 Wabash Ave., Kansas City, Mo. '31
Keith, Arthur, 2210 Twentieth St., Washington, D. C. '29
Keller, P. Hastings, 628 S. Elmwood Ave., Oak Park, Ill. '26
Keller, Walter T., North Venezuelan Petr. Co., Ltd., Puerto Cabello, Venezuela, S. A. '27
Kelley, Ward W., Carrier #109, San Antonio, Tex. '29
Kellum, Lewis B., University Museum, Univ. of Michigan, Ann Arbor, Mich. '25
Kelly, Donald, Box 999, Wichita Falls, Tex. '24
||Kelly, Pennell C., 1504 Ave. Q, Lubbock, Tex. (Mail returned) '28
||Kemnitzer, Luis E., 1201 E. California St., Pasadena, Calif. '29
||Kemp, Augusta H., Box 626, Seymour, Tex. '26
||Kemp, Harold S., Box 1865, Houston, Tex. '29
Kendrick, Frank E., Lone Star Gas Co., Dallas, Tex. '20
Kennard, Harry C., Pennsville, Ohio '30
||Kennedy, Gilbert R., Magnolia Petr. Co., Dallas, Tex. '30
Kennedy, J. B., Box 1326, Ranger, Tex. '26
Kennedy, Luther E., 1735 S. Victor, Tulsa, Okla. '19
Kent, Joseph T., 3551 University Blvd., Dallas, Tex. '19
Keppler, Leo G., 1529 S. Owasso, Tulsa, Okla. '21
||Kerbow, Russell B., Drawer C, Houston, Tex. '30
Kernan, Thomas H., 5003 Victor St., Dallas, Tex. '20
Kerr, John B., Hawkins Bros., Foreman, Ark. '20
Kerr, Richard C., Continental Air Map Co., 114 S. Beaudry St., Los Angeles, Calif. '27
Kesler, L. W., 527 First Natl. Bank Bldg., Wichita, Kan. '19
||Kesler, Thomas L., Box 86, Salisbury, N. C. '31
||Kessler, D. Lowell, 2009 S. Sherman, Denver, Colo. '28
Kew, W. S. W., Standard Oil Co., Box 1390, Station C, Los Angeles, Calif. '21
||Keyes, Wilson, c/o George W. Keyes, Monte Vista (R.A.), Colo. '25
||Keyte, W. Ross, Tulsa University, Room 4, Engineering Bldg., Tulsa, Okla. '28
Kidd, Gentry, 1214 Avenue D, San Angelo, Tex. '29
||Kiess, Myron C., Pure Oil Co., 64 N. Fourth St., Newark, Ohio '27
Kihlstedt, Folke H., 26 Beaver St., 12th Floor, New York, N. Y. '31
Kimball, E. B., 1810 Electric Bldg., Fort Worth, Tex. '27
Kimball, Kent K., 1804 W. Easton St., Tulsa, Okla. '22
King, Charles C., 804 Wright Bldg., Tulsa, Okla. '27
King, Philip B., U. S. Geological Survey, Washington, D. C. '25
King, Robert E., Box 533, Iowa City, Iowa '31
King, Vernon L., 427 N. Fuller Ave., Los Angeles, Calif. '23
Kinkel, John F., Hardman Lumber Co., Wakeeney, Kan. '25
Kinkel, W. C., Box 728, San Angelo, Tex. '23
Kinney, Harry D., Research Dept., Chase Natl. Bank, 11 Broad St., New York, N. Y. '24
Kirby, Grady C., 1736 Milam Bldg., San Antonio, Tex. '19
Kirby, James M., 225 Bush St., San Francisco, Calif. '27
||Kirby, Louie C., Box 202, Gentry, Ark. '31
Kirk, Charles T., Box 1592, Tulsa, Okla. '17
Kirk, Howard M., Mexico-Texas Petrolene & Asphalt Co., Apartado 285, Tampico, Mexico '27
Kirkham, Virgil R. D., 505 Bearringer Bldg., Saginaw, Mich. '30
Kisling, James W., Jr., Amerada Petr. Corp., Tyler, Tex. '27
Kister, Herbert H., 400 Masonic Bldg., Shawnee, Okla. '26
Kitchin, Walter, Iraq Petr. Co., Ltd., Kirkuk, Iraq '31
Kite, William C., 704 Braniff Bldg., Oklahoma City, Okla. '17
||Kittredge, Frank R., 656 N. Beard St., Shawnee, Okla. '27
Kittredge, M. B., 656 N. Beard St., Shawnee, Okla. '25
Klaus, Hellmut, c/o W. B. Wilson, Gypsy Oil Co., Box 661, Tulsa, Okla. '28
||Kleinpell, Robert M., Box 821, Stanford University, Calif. '29
Kleinpell, William D., Box 1131, Bakersfield, Calif. '25
Klingaman, George L., The California Co., Midland, Tex. '25
Klinger, Edgar D., 502 S. Adams St., San Angelo, Tex. '27
Kluth, Emil, G. F. Getty, Inc., 1060 Subway Terminal Bldg., 417 S. Hill St., Los Angeles, Calif. '27

Knappen, Russell S., Gypsy Oil Co., Box 661, Tulsa, Okla. .... '20
Kneale, William C., The Texas Co., Box 983, Fort Worth, Tex. .... '27
Knebel, G. Moses, Standard Oil Co. of Venezuela, Caripito, Venezuela via Trinidad, B. W. I. .... '24
||Knight, J. Brookes, Peabody Museum, Yale University, New Haven, Conn. .... '31
Knight, Oliver B., Box 696, McAllen, Tex. .... '28
Kniker, Hedwig T., Alamo Natl. Bldg., San Antonio, Tex. .... '21
Knode, William F., Jr., 1007 E. Grand, Tonkawa, Okla. .... '27
||Koester, Edward A., 1702 Fairmount Ave., Wichita, Kan. .... '29
Knox, George L., The California Co., 342 Continental Oil Bldg., Denver, Colo. .... '27
Knox, John K., Phillips Petr. Co., Bartlesville, Okla. .... '19
Knox, T. K., 1114 Tower Petroleum Bldg., Dallas, Tex. .... '29
Knutson, C. J., 1710 Union Bank Bldg., Pittsburgh, Pa. .... '27
Kobayashi, Giichiro, 310 Zoshigaya, Tokyo-fuka, Japan .... '25
Koch, Richard E., 30 Carel van Bylandtlaan, The Hague, Holland .... '28
Koch, Thomas W., Standard Oil Co., Bin XX, Taft, Calif. .... '25
Koenig, Ralph A., Box 548, Carlsbad, N. Mexico .... '32
||Kohler, F. W., 120 W. Main St., Greenville, Pa. .... '30
Kolm, Robert N., Atlantic Oil Prod. Co., Magnolia Bldg., Dallas, Tex. .... '19
||Kolm, Paul H., Box 685, Pratt, Kan. (Mail returned) .... '30
||Kornfeld, M. M., Box 1119, Houston, Tex. .... '27
Kraft, Philip, 14 Wall St., Room 1500, New York, N. Y. .... '27
Kramer, William B., 606 Eleventh St., Ballinger, Tex. .... '26
Krampert, E. W., Drawer A, Parco, Wyo. .... '23
Kraus, Edgar, Box 566, Carlsbad, N. Mexico .... '20
Krejci, Karl, Sun Yatsen University, Dept. of Paleontology, Canton, China .... '31
Kridler, George M., Deep Rock Oil Corp., Atlas Life Bldg., Tulsa, Okla. .... '26
Kroenlein, George A., Box 22, Carlsbad, N. Mexico .... '22
Krueger, Max L., Western Gulf Oil Co., 1221 Subway Terminal Bldg., Los Angeles, Calif. .... '25
Kugler, Hans G., Trinidad Leaseholds, Ltd., Point-a-Pierre, Trinidad, B. W. I. .... '27
Kuiper, W. N., Apartado 150, Tampico, Mexico .... '28
Kurtz, Robert G., Ohio Oil Co., Casper, Wyo. .... '31

La Croix, Morris F., 82 Devonshire St., Boston, Mass. .... '21
Ladd, Harry S., c/o R. S. Bassler, U. S. National Museum, Washington, D. C. .... '30
||Lafferty, Robert C., Jr., Box 1240, Charleston, W. Va. .... '30
Lahee, Frederic H., Box 2880, Dallas, Tex. .... '19
||Laiming, Boris G., The Texas Co., Geological Dept., 929 S. Broadway, Los Angeles, Calif. .... '28
Lake, Charles L., Garden Grove, Calif. .... '28
Lake, Francis W., Union Oil Co., Santa Fe Springs, Calif. .... '24
Lamb, R. C., Barnsdall Oil Co., Box 97, Earlsboro, Okla. .... '28
Lambert, Gerald S., Phillips Petr. Co., Bartlesville, Okla. .... '28
Lane, Alfred C., 22 Arlington St., Cambridge B., Mass. .... '24
||Lane, Charles W., 1 Fairfield St., Salem, Mass. .... '29
Lang, W. B., U. S. Geological Survey, Washington, D. C. .... '25
Langworthy, A. A., 415 W. Twelfth St., Apt. 3, Tulsa, Okla. .... '21
LaPeire, George W., United Fuel Gas Co., Box 1256, Charleston, W. Va. .... '26
Larkin, Pierce, 1440 S. Norfolk, Tulsa, Okla. .... '23
Larsh, N. B., Sinclair Oil & Gas Co., Box 675, San Angelo, Tex. .... '30
Larsh, Walter W., 413 First Natl. Bank Bldg., Wichita, Kan. .... '25
La Rue, James E., Humble Refg. Co., Houston, Tex. .... '20
Laskey, G. E., 710 N. Vienna St., Ruston, La. .... '21
Lasky, Bernard H., 907 Atlas Life Bldg., Tulsa, Okla. (Mail returned) .... '19
La Touche, John D., Sun Oil Co., Beaumont, Tex. .... '31
Lauer, A. W., The Texas Co., Box 2420, Tulsa, Okla. .... '21
Laughbaum, Graydon H., Sinclair Prairie Oil Co., Box 518, Covington, Okla. .... '31
Laughlin, R. W., 800 E. Seventeenth St., Oklahoma City, Okla. .... '23
Lavington, Charles S., 1914 Leyden St., Denver, Colo. .... '24
Lawson, Andrew C., Univ. of California, Berkeley, Calif. .... '27
||Lawton, Joe, 205 Ira Ave., San Antonio, Tex. .... '27

||Lay, Henry C., Venezuela Gulf Oil Co., Apartado 35, Cuidad Bolivar, Venezuela, S. A. .... '30
Leach, Thomas W., 511 E. Mohawk Blvd., Tulsa, Okla. .... '25
||Leach, Walter W., Groesbeck, Tex. .... '31
||Leatherock, Constance, 1530 E. Fourteenth St., Apt. C-5, Tulsa, Okla. .... '29
Leavenworth, Paul B., Box C, Houston, Tex. .... '26
Lebkicher, Roy, The California Co., Box 1431, Great Falls, Mont. .... '27
Lee, Clarence L., Wahoo, Neb. .... '31
Lee, Huylar W., 513 City Natl. Bank Bldg., Wichita Falls, Tex. .... '25
Lee, Lynn K., Pure Oil Co., 35 E. Wacker Drive, Chicago, Ill. .... '28
Lee, Marvin, 1103 Brown Bldg., Wichita, Kan. .... '17
||Lee, Thomas W., 209 S. First St., Independence, Kan. .... '29
Lee, Wallace, Box 446, Okmulgee, Okla. .... '20
Lees, George M., Anglo Persian Oil Co., Ltd., Britannic House, Finsbury Circus, London, E. C. 2, England .... '31
Lehman, Roy P., R. R. 1, Box 42, Halstead, Kan. .... '26
Lehner, Ernest J., Trinidad Leaseholds, Ltd., Point-a-Pierre, Trinidad, B. W. I. .... '29
Leibensperger, Raymond, Wassenaarscheweg 117, The Hague, Holland .... '18
Leidhold, Clemens, Yacimiento Petr. Fiscal Chubut, Comodoro Rivadavia, Chubut, Argentina, S. A. .... '30
Leighton, Morris M., 305 Ceramics Bldg., Urbana, Ill. .... '24
Leiser, J. B., Box 1191, Tulsa, Okla. .... '26
Lemley, G. C., Box 23, Mount Morris, Pa. .... '21
Lepper, G. W., Burmah Oil Co., Ltd., Nyounghla, Magwe District, Upper Burma, India .... '25
Lesniak, Stanislaw W., 2729 Fullerton Ave., Chicago, Ill. .... '25
Lester, O. C., Jr., Geophysical Research Corp., Drawer 2040, Tulsa, Okla. .... '29
Levings, W. S., 219 E. Seventeenth Ave., Denver, Colo. .... '23
Levorsen, A. Irving, 1740 S. St. Louis, Tulsa, Okla. .... '19
Lewis, Frank E., 1316 S. David, San Angelo, Tex. .... '21
Lewis, James O., 507 Commercial Bldg., Tulsa, Okla. .... '19
Lewis, J. Volney, 6 Linden Place, New York, N. Y. .... '23
Lewis, J. Whitney, 5645 Gaston Ave., Dallas, Tex. .... '23
||Lewis, Paul S., Box 57, Golden, Colo. .... '30
Ley, Henry A., Rio Oil Corp., 706 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. .... '19
Leyds, Louis W., Dedelstraat 11, The Hague, Holland .... '27
Libbey, D. S., 1162 Mt. Vernon, Springfield, Mo. .... '30
Liddle, R. A., Pure Oil Co., Box 1007, Fort Worth, Tex. .... '20
Lieb, Victor E., 2027 Rosedale Ave., Houston, Tex. .... '24
Lilley, Ernest R., 104 Graham Ave., Paterson, N. J. .... '28
Lillibridge, Harry E., 1501 W. Oklahoma, Enid, Okla. .... '28
Lilligren, J. M., Box 254, Enid, Okla. .... '21
Lincoln, B. W., 733 E. Twentieth St., Oklahoma City, Okla. .... '28
Lindeblad, E. E., 506 N. Osborne Ave., Oakland, Neb. .... '19
||Lindeblad, L. C., 506 N. Osborne, Oakland, Neb. .... '30
Lindtrop, Norbert, Trust "Sredasneft" Kokand (Usbekistan), U. S. S. R. .... '26
Link, Theodore A., Museum of Science & Industry, 1525 E. Fifty-Third St., Chicago, Ill. .... '21
Link, Walter K., Ned. Kol. Petr. Mij., Batavia Centrum, Java, D. E. I. .... '30
Littlefield, Max S., Box 661, Tulsa, Okla. .... '31
Livingston, Noyes B., 2505 Sixth Ave., Fort Worth, Tex. .... '26
||Livingstone, Jennie, 1433 S. Frisco, Tulsa, Okla. .... '28
Lloyd, Abe M., Box 1215, Shreveport, La. .... '21
Lloyd, E. Russell, Box 1106, Midland, Tex. .... '21
Lockett, J. R., 1654 Genessee Ave., Linden, Columbus, Ohio .... '28
||Lockwood, R. P., 1090 Eleventh St., Apt. 10, Boulder, Colo. .... '30
Loel, Wayne, 812 Subway Terminal Bldg., Los Angeles, Calif. .... '22
Logan, Clarence Z., 704 Natl. Bank of Commerce Bldg., Tulsa, Okla. .... '20
Logan, David M., Okmulgee, Okla. .... '25
||Logie, Russell Moore, Peabody Museum, New Haven, Conn. .... '31
||Lohman, Mary Kathryn, c/o K. E. Lohman, U. S. Geological Survey, Washington, D. C. .... '31
||Lokman, Kemal, Ministry of Economy, Mining Dept., Ankara, Turkey .... '31

Long, Carl T., Hillman-Long, Inc., 1052 Subway Terminal Bldg., Los Angeles, Calif. '25
Longmire, William R., Box 661, Tulsa, Okla. '20
||Longnecker, Oscar M., Jr., 3218 Ella Lee Lane, Houston, Tex. '26
Lonsdale, John T., College Station, Tex. '29
Loomis, Harve, Box 1344, Abilene, Tex. '17
Loskamp, Alvin P., Barnsdall Oil Co., Midland, Tex. '25
||Lott, Frederick S., 20 MacKay Place, Brooklyn, N. Y. '30
Louderback, George D., Univ. of California, Berkeley, Calif. '25
Lounsbery, D. E., Phillips Petr. Co., Box 816, San Angelo, Tex. '21
||Love, Perry R., c/o Lee Love, Rolla, Mo. '30
Lovejoy, J. B., Gulf Prod. Co., Box 737, Fort Worth, Tex. '27
Lovejoy, John M., Seaboard Oil Co. of Delaware, 39 Broadway, New York, N. Y. '24
Lovering, T. S., U. S. Geological Survey, Golden, Colo. '31
Lowe, Ephraim N., Mississippi Geological Survey, University, Miss. '21
Lowe, William F., 1607 E. Twelfth St., Apt. 203, Tulsa, Okla. '30
Lowman, Shepard W., Mid-Continent Petr. Corp., Box 2025, Tulsa, Okla. '26
||Lucke, John B., 110 Riverside Drive, New York, N. Y. '30
Lucky, M. C., 2007 Quenby Road, Houston, Tex. '26
Luecke, Lester A., Colombian Petr. Co., Apartado 100, Cucuta, Colombia, S. A. '25
Lugn, A. L., Univ. of Nebraska, Geological Dept., Lincoln, Neb. '31
Luman, Edmondson D., Atlantic Oil Prod. Co., Beacon Life Bldg., Tulsa, Okla. '24
Lund, Gage V., The California Co., Tower Petroleum Bldg., Dallas, Tex. '27
Lupton, Charles T., 617 Gilpin St., Denver, Colo. '20
||Lyle, John Gerald, 55 E. Twentieth St., Apt. 12, Portland, Ore. '30
Lyle, W. M., 501 Capps Bldg., Fort Worth, Tex. (Mail returned) '27
Lynn, Robert H., Phillips Petr. Co., Box 665, Amarillo, Tex. '21
Lynton, Edward D., Standard Oil Co., Box 1390, Station C, Los Angeles, Calif. '23
Lyons, Richard T., Box 1650, Tulsa, Okla. '22
||Lyster, Marvin E., Box 1650, Dallas, Tex. (Mail returned) '25
||Lytel, Harvey M., 2525 E. Thirty-Seventh St., Los Angeles, Calif. '28
||Lytle, J. Edward, Box 1349, Monroe, La. '31

MacDonald, Erwin H., 508 Securities Bldg., Billings, Mont. '23
MacDonell, James A., 632 W. Market St., Lima, Ohio '25
Macfadyen, William A., Longships, Capel-le-Ferne, nr. Folkestone, England '25
Mackay, Donald K., 15 Glover Ave., Yonkers, N. Y. '25
MacKay, Hugh, 706 S. Poplar St., Sapulpa, Okla. '17
Mackenzie, Andrew N., Apartado 683, Caracas, Venezuela, S. A. '22
MacNaughton, Lewis W., 1718 Milam Bldg., San Antonio, Tex. '26
Macpherson, Eric O., Taranaki Oil Fields, Ltd., Box 9, Gisborne, New Zealand '27
Macready, George A., 5425 Chesley Ave., Los Angeles, Calif. '19
Maddox, Gerald C., 2112 N. Villa, Oklahoma City, Okla. '29
Maddox, Walter H., Apartado 141, Monterrey, N. L., Mexico '31
||Magalis, Cyrus W., 106 W. South St., Longview, Tex. (Mail returned) '27
||Mahon, Margaret F., 2704 Rogers Ave., Fort Worth, Tex. '29
||Mahoney, R. F., Box 508, Stanford University, Calif. '31
||Malamphy, Mark C., Servico Geologico e Mineralogico do Brazil, Praia Vermelha, Rio de Janeiro, S. A. '30
Maley, Vaughan C., Humble Oil & Refg. Co., McCamey, Tex. '28
Maley, Willis A., 204 Nixon Bldg., Corpus Christi, Tex. '29
Maness, Orie N., 2628 E. Admiral Blvd., Tulsa, Okla. '31
Manion, Clarence E., 1776 Krameria St., Denver, Colo. '27
Mannen, Richard Lee, 323 Bushnell Place, San Antonio, Tex. '29
Manning, Lloyd R., 1007 S. Adams St., Fort Worth, Tex. (Mail returned) '30
||Marie, Marcel, Cie Fse des Petroles, 63 Ave. Victor Emmanuel, Paris, France '31
||Maris, Harold W., 119 N. Elm, Ponca City, Okla. '29
Markham, Edmond O., Carter Oil Co., Box 801, Tulsa, Okla. '20
Markley, Elmer A., Barnsdall Oil Co., Geological Dept., Tulsa, Okla. '23
Markley, Joseph H., Jr., The Texas Co., Box 999, Wichita Falls, Tex. '28
||Marr, John D., Weldona, Colo. '29
Marsters, Vernon F., Box 513, Winnsboro, Tex. '18
Marston, R. L., Box 807, Tyler, Tex. '25

||Martin, B. G., Healdton, Okla. '30
Martin, Francis I., Apartado 263, Caracas, Venezuela, S. A. '23
Martin, Frederick O., 2038 Pine St., S. Pasadena, Calif. '25
Martin, George C., 3126 Thirty-Eighth St., Washington, D. C. '24
Martin, Helen M., 119 Genessee, Lapeer, Mich. '25
Martin, Henry G., Sta. R. R. 5, Box 324, Lockland, Ohio '30
Martin, Hugh B., 488 Lilac Drive, Santa Barbara, Calif. '31
Martin, P. M., Box 754, Coleman, Tex. '29
Martinet, Guy M., 704 S. Poplar, Sapulpa, Okla. '29
Martyn, Phillip F., Houston Oil Co. of Texas, Box 1779, Houston, Tex. '28
Mason, Shirley L., 1617 Millard St., Bethlehem, Pa. '19
Masterson, Reba B., Menger Hotel, San Antonio, Tex. '23
||Matheny, H. C., Box 5030, Shawnee, Okla. '27
Mather, Kirtley F., Geological Museum, Oxford St., Cambridge, Mass. '21
||Mathes, Donald E., 1811 Petroleum Bldg., Houston, Tex. '23
Matson, George C., 1534 E. Seventeenth Place, Tulsa, Okla. '19
Matson, Martin, 1922 W. Gramercy, San Antonio, Tex. '25
Matteson, Wallace G., Box 376, Center Moriches, Long Island, N. Y. '18
Maucini, Joseph J., Continental Oil Co., Geological Dept., Wichita Falls, Tex. '27
Maverick, Phillip, Western Reserve Life Bldg., San Angelo, Tex. '23
||Maxwell, Joseph M., 826 S. Pearl St., Denver, Colo. '31
||Maxwell, Riley G., Box 886, San Angelo, Tex. '30
May, Art R., 405 Haberfelde Bldg., Bakersfield, Calif. '21
May, John C., 302 W. Anapamu St., Santa Barbara, Calif. '33
||McArthur, Donald, McHenry, Miss. '20
McAuliffe, G. C., Drawer 1346, Monroe, La. '32
||McCallum, Henry D., 2015 Smith-Young Tower, San Antonio, Tex. '31
||McCarter, W. Blair, Humble Oil & Refg. Co., Geological Dept., Houston, Tex. '27
||McCartney, Joy A., Box 451, San Angelo, Tex. '26
McCaskey, Morgan E., 3800 Monticello Drive, Fort Worth, Tex. '29
||McClain, Alan H., United Fuel Gas Co., Geological Dept., Charleston, W. Va. '32
McClellan, Hugh W., 120 E. Sixth Ave., Hutchinson, Kan. '27
McCluer, R. D., 3112 Rice Blvd., Houston, Tex. '22
McClure, J. H., Prairie Oil & Gas Co., Midland, Tex. '31
||McCobb, Harry W., Tropical Oil Co., Barranca-Bermeja, Colombia, S. A. '28
McCollom, C. R., 705 Richfield Bldg., 555 S. Flower St., Los Angeles, Calif. '23
McCollough, Edward H., 6108 Barrows Drive, Los Angeles, Calif. '24
McCollum, Leonard F., 2015 Smith-Young Tower, San Antonio, Tex. '27
||McConnell, Fred I., 1036 Milam Bldg., San Antonio, Tex. (Mail returned) '31
McCoy, Alex. W., 919 E. Grand Ave., Ponca City, Okla. '17
McCrary, E. W., Box 861, Tulsa, Okla. '18
McCulloch, Joseph P., 7 Cleveland Lane, Princeton, N. J. '26
McCullough, A. S., Clifton, Greene County, Ohio '17
McCullough, R. L., Box 306, Great Bend, Kan. '25
McDermott, Eugene, 1311 Republic Bank Bldg., Dallas, Tex. '29
McDonald, Worth W., 324 E. Rosewood, San Antonio, Tex. '24
||McFarland, Earl R., Broadview Hotel, Oklahoma City, Okla. '30
McFarland, Paul W., Box 2880, Dallas, Tex. '23
McFarland, R. S., 1002 First Natl. Bank Bldg., Dallas, Tex. '18
McFerron, George I., Adams Royalty Co., 502 Natl. Bank of Commerce Bldg., Tulsa, Okla. '22
†McGaha, Charles P., 607 Hamilton Bldg., Wichita Falls, Tex. '29
McGee, D. A., 1204 Petroleum Bldg., Oklahoma City, Okla. '29
||McGehee, Rex, 1536 N. W. Thirteen St., Oklahoma City, Okla. '30
||McGhee, George C., 464 College, Norman, Okla. (Mail returned) '31
McGill, Andrew K., Tropical Oil Co., Apartado 170, Cartagena, Colombia, S. A. '25
||McGill, William M., 303 E. High St., Charlottesville, Va. '26
McGirl, James N., 523 S. Zunis, Tulsa, Okla. '25
McGlothlin, Tom, 527 N. Douglass, Shawnee, Okla. '29
McGlothlin, William C., 2121 W. Fourth Ave., Corsicana, Tex. '31
McGovern, Rudolph A., Eleven Broadway, New York, N. Y. '26
||McGowan, F. H., Box 193, Smithville, Tex. '29
||McIntyre, George T., 408 N. Delaware, Butler, Mo. '30

McIntyre, Paul J., Phillips Petr. Co., Bartlesville, Okla. '19
‖McKague, Bruce C., Box 852, San Angelo, Tex. '25
McKanna, Edwin A., 801 Columbia St., S. Pasadena, Calif. '21
‖McKay, A. E., Box 2082, Tulsa, Okla. '30
McKee, H. Harper, Room 1745, 120 Broadway, New York, N. Y. '17
McKenna, John S., 4731 E. Fifty-Second Drive, Los Angeles, Calif. '26
McLaren, Robert L., Box 623, Victor, Colo. '27
‖McLaughlin, Homer C., Box 703, Duncan, Okla. '21
McLellan, Hiram J., Humble Oil Co., Box 598, Tyler, Tex. '20
McLeod, Angus, Shell Petr. Corp., Box 2099, Houston, Tex. '19
McMillan, Joseph M., Jr., 2109 Avenue P, Galveston, Tex. '27
McNeely, Robert, 709 Ellis-Singleton Bldg., Wichita, Kan. '25
McNutt, Vachel H., 1005 Frost Bank Bldg., San Antonio, Tex. '21
McWhirt, Burr, 116 E. Eufala St., Norman, Okla. '18
Mead, Roy G., 1220 Chapman Bldg., Los Angeles, Calif. '31
‖Mechling, George W., 1995 Park Ave., Lincoln, Neb. '32
Meland, Norman, 707 Braniff Bldg., Oklahoma City, Okla. '22
Melcher, A. F., 1137 N. Cheyenne, Tulsa, Okla. '22
Mellen, William P., 4846 Tennyson St., Denver, Colo. '31
Mendelsohn, Clive A., 24 Priory Court, West Hampstead, London, England '31
Mendenhall, Walter C., U. S. Geological Survey, Washington, D. C. '22
Menke, John H., 225 Bush St., San Francisco, Calif. '29
Menken, Fred A., Associated Oil Co., San Francisco, Calif. '32
Meredith, Carlton, 202 Spencer Bldg., Cisco, Tex. '20
Merritt, Floyd C., 4731 E. Fifty-Second Drive, Los Angeles, Calif. '23
Merritt, J. W., 1324 E. Seventeenth Place, Tulsa, Okla. '18
Merritt, Roy W., 80 Broad St., 28th Floor, New York, N. Y. '29
Merry, Edward T., Box 606, Fort Worth, Tex. '25
Mershon, Milton M., 1801 W. Mulberry, San Antonio, Tex. '25
‖Metcalf, Myron C., Box 324, Huntsville, Tex. '30
Metcalf, Roy J., 1605 W. T. Waggoner Bldg., Forth Worth, Tex. '26
Meyer, Arthur M., Box 1103, Beeville, Tex. '21
Meyers, Percy A., 1713 Third St., Corpus Christi, Tex. (Mail returned) '25
‖Michaux, Frank W., Jr., 2419 Southmore Blvd., Houston, Tex. '31
Milek, Andrew, Mexican Sinclair Petr. Corp., Apartado 241, Tampico, Mexico '22
Millard, William J., Box 488, Texon, Tex. '19
‖Miller, Albert Douglas, Dept. of Conservation, 304 Ward Bldg., Shreveport, La. '30
Miller, Carroll C., Box 787, Beeville, Tex. '25
Miller, David B., 1336 Gaylord St., Denver, Colo. '29
Miller, E. Floyd, 1518 S. Utica, Tulsa, Okla. '24
Miller, Forrest J., 1531 Peachtree St., Jackson, Miss. '22
Miller, Guy E., 205 Professional Bldg., Long Beach, Calif. '25
‖Miller, Harry A., Box 122, Crescent, Okla. '28
Miller, John C., The Texas Co., Houston, Tex. '28
Miller, Milward, Humble Oil & Refg. Co., Roswell, N. Mexico '33
Miller, Robert P., Bahrain, Persian Gulf '28
Miller, Wendell Z., 942 Kennedy Bldg., Tulsa, Okla. '21
Miller, Willard L., 2647 W. Fifteenth St., Oklahoma City, Okla. '19
‖Miller, William C., 460 Washington St., Denver, Colo. '31
Miller, William Dana, Apartado 478, Caracas, Venezuela, S. A. '31
‖Miller, W. Keith, 924 S. Twentieth St., Lincoln, Neb. '30
Millikan, C. V., Drawer 2040, Tulsa, Okla. '20
Millison, Clark, Box 1191, Tulsa, Okla. '27
Mills, Coe S., 212 E. Front St., Tyler, Tex. '27
Mills, R. van A., Continental Oil Co., Ponca City, Okla. '21
Milner, Charles A., Jr., 105 C St., S. W., Ardmore, Okla. '25
Milner, Henry Brewer, 92 Victoria St., Westminster, London, S. W. 1, England '31
Milstein, M., c/o Sta. M. Pacheco, Bucarelli 148, Apartado 3, Mexico, D. F., Mexico '28
Minor, H. E., Gulf Prod. Co., Houston, Tex. '18
Mintrop, Ludger, Koenigshof, Hannover, Germany '31
Miser, Hugh D., U. S. Geological Survey, Washington, D. C. '23
‖Mitcham, Bill S., 406 Avenue I, Cisco, Tex. (Mail returned) '30

||Mitcham, James R., 117 W. Lee, Brownwood, Tex. ... '28
Mitchell, Ralph H., Coombe Cottage, Butler's Dene Road, Woldingham, Surrey, England ... '25
||Mitchell, Robert B., Stanolind Oil & Gas Co., Box 788, Pampa, Tex. ... '29
||Mitchell, William H., 3325 St. Johns Drive, Dallas, Tex. ... '29
Mix, C. A., The California Co., Drawer R, Midland, Tex. ... '26
Mix, Sidney E., 902 Unadilla, Shreveport, La. ... '22
Mohr, C. L., Box 811, San Angelo, Tex. ... '25
Moir, John, c/o J. C. Jackson, Eagle, Chambers County, Tex. ... '26
Moncrief, E. C., Derby Oil Co., Wichita, Kan. ... '23
Monnett, V. Elvert, 723 White St., Norman, Okla. ... '19
||Monroe, Watson H., U. S. Geological Survey, Washington, D. C. ... '31
||Monsour, Eli B., Apartado 94, Tampico, Tamps., Mexico ... '30
||Montgomery, A. J., 801 E. Oak, Cushing, Okla. ... '29
Montgomery, James G., Jr., 308 Seneca St., Oil City, Pa. ... '26
||Montgomery, Phil C., Box 387, Chickasha, Okla. ... '31
Moody, Clarence L., Ohio Oil Co., Giddens Lane Bldg., Shreveport, La. ... '20
Moody, Graham B., Box 1390, Station C, Los Angeles, Calif. ... '27
||Moody, Ray R., Box 2097, Denver, Colo. ... '27
||Moore, Barton W., Blackstone Hotel, Tyler, Tex. ... '31
Moore, Gilbert P., Room 1047, 25 Broadway, New York, N. Y. (Mail returned) ... '24
Moore, Hastings, 306 Methvin, Longview, Tex. (Mail returned) ... '27
Moore, John I., Holcombe-Blanton Bldg., San Angelo, Tex. ... '26
Moore, Kenneth B., 1748 S. Wheeling, Tulsa, Okla. ... '29
||Moore, Marcus H., 3150 Waits, Fort Worth, Tex. ... '29
Moore, Prentiss D., Holcombe-Blanton Bldg., San Angelo, Tex. ... '26
Moore, Raymond C., Univ. of Kansas, Lawrence, Kan. ... '17
Moran, Robert B., 215 W. Seventh, Los Angeles, Calif. ... '19
||Moree, Robert W., 903 Humble Bldg., Houston, Tex. ... '30
Morero, Joseph E., Box 1485, Midland, Tex. ... '23
Morgan, Ben F., Box 96, Falls City, Neb. ... '31
||Morgan, Cecil L., 118 W. Avenue H, San Angelo, Tex. ... '29
||Morgan, Charles Gill, 4608 Abbott Ave., Dallas, Tex. ... '31
||Morgan, D. E., 99 Carmarthen Road, Waun Wen Swansea, Glam., England ... '28
Morgan, D. M., Wentz Oil Corp., Ponca City, Okla. ... '25
Morgan, Frank A., 774 Subway Terminal Bldg., Los Angeles, Calif. ... '24
Morgan, George D., Hilton Bldg., San Angelo, Tex. ... '22
Morgan, Henry J., Jr., Atlantic Oil Prod. Co., San Angelo, Tex. ... '28
Morgan, L. C., Box 677, Wichita, Kan. ... '30
||Morgan, Lindsey G., 763 Jenkins, Norman, Okla. (Mail returned) ... '30
Morley, Harold T., Stanolind Oil & Gas Co., Box 591, Tulsa, Okla. ... '19
Morris, A. Ferd, 1100 Keeler, Bartlesville, Okla. ... '21
Morris, Walter W., Eagle-Picher Mining & Smelting Co., Oil & Gas Dept., Henryetta, Okla. ... '24
||Morrison, T. E., 310 B. Annex Humble Bldg., Houston, Tex. ... '27
Morse, Roy R., Shell Co. of Calif., 429 Higgins Bldg., Los Angeles, Calif. ... '24
Morse, W. C., Mississippi State College, State College, Miss. ... '21
Mosburg, Lewis G., Stanolind Oil & Gas Co., Philcade Bldg., Tulsa, Okla. ... '26
||Moser, Charles Eugene, 555 S. Flower St., Los Angeles, Calif. ... '30
Moses, Harold F., Apartado 285, Tampico, Mexico ... '29
Moss, Frank A., Oil Search Ltd., 350 George St., Sidney, N. S. W., Australia ... '29
Mossom, Stuart, 2517 Smith Young Tower, San Antonio, Tex. ... '29
Moulton, Gail F., 2 Rector St., New York, N. Y. ... '23
Mower, Lowell K., Wittenbugerweg 7, Wassenaar, Holland ... '25
Muehlberg, M., Aarau, Switzerland ... '25
||Muir, J. Lawrence, 612 S. Lahoma, Norman, Okla. ... '30
Muir, John M., 706 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. ... '24
||Muldrow, Robert, Jr., 403 Burt Bldg., Dallas, Tex. ... '28
Mullins, William B., 1128 N. Broadway, Shawnee, Okla. ... '28
Munn, M. J., Longview Hotel, Longview, Tex. ... '19
Munoz, Robert R., Petroleum Finance Corp., 42 Broadway, New York, N. Y. ... '30
Munroe, Donald J., Box 753, Jackson, Miss. ... '28
Munson, Robert E., c/o Dr. D. O. Munson, Pittsburg, Kan. ... '23

||Munyan, Arthur C., 267 E. High St., Lexington, Ky. .... '32
Murayama, K., No. 211, Koenji, Suginami-machi, near Tokyo, Japan .... '32
||Murchison, Eugene A., Jr., Humble Oil & Refg. Co., Box 598, Tyler, Tex. .... '30
Murphy, Earle N., 1823 W. Cleveland, Guthrie, Okla. .... '23
Murphy, James K., 1731 S. College, Tulsa, Okla. .... '28
||Murphy, John A., 1431 S. Cincinnati, Tulsa, Okla. .... '30
Murphy, P. C., Humphreys Corp., Esperson Bldg., Houston, Tex. .... '25
Murray, A. N., Univ. of Tulsa, Geological Dept., Tulsa, Okla. .... '30
Myers, Desaix B., Union Oil Co. of Calif., Union Oil Bldg., Los Angeles, Calif. ... '25
||Myers, Joe L., 2413 Isabella, Houston, Tex. (Mail returned) .... '30
Myers, John C., 3707 Graustark St., Houston, Tex. .... '22
Myers, Julian Q., 1118 City Natl. Bank Bldg., San Antonio, Tex. .... '23
||Mygdal, Karl A., Standard Oil Co. of Venezuela, Caripito, Venezuela, via Trinidad, B. W. I. .... '30
Mylius, L. A., 266 W. Twentieth St., Hutchinson, Kan. .... '21

Nance, Albert G., Box 737, Fort Worth, Tex. .... '27
Naramore, Chester, Crandall & Osmond, 17 Battery Place, New York, N. Y. ...... '21
Nash, Howard F., Box 623, Polson, Mont. .... '20
Neal, Earl S., Apartado 172, Maracaibo, Venezuela, S. A. .... '30
Nedom, Harry A., Box 322, Okmulgee, Okla. .... '29
||Neel, Merrill A., Tecumseh, Okla. .... '27
||Neill, Dewitte E., Box 191, Clinton, Okla. .... '30
Nelimark, John H., 803 Ninth Ave., S. E., Minneapolis, Minn. .... '28
||Nelson, Floyd A., Shell Petr. Corp., Geological Dept., St. Louis, Mo. .... '30
||Nelson, Fred M., Texas Gulf Sulphur Co., Newgulf, Tex. .... '25
||Nelson, James C., 1632 Milam Bldg., San Antonio, Tex. .... '29
Nelson, Jean O., 1919 W. Magnolia St., San Antonio, Tex. .... '22
Nelson, Richard N., 1102 Standard Oil Bldg., San Francisco, Calif. .... '26
Nelson, Walter S., Box 1304, Billings, Mont. .... '20
Nelson, Wilbur A., Univ. of Virginia, Charlottesville, Va. .... '20
Nessly, Howard E., 1717 W. Mulberry St., San Antonio, Tex. .... '25
Netick, Joe, Apartado 168, Maracaibo, Venezuela, S. A. .... '29
||Nettleton, L. L., Gulf Research Lab., 327 Craft Ave., Pittsburgh, Pa. .... '30
Neumann, Fred R., 6261 Hyacinth St., Chicago, Ill. .... '31
Neumann, L. Murray, Carter Oil Co., Box 801, Tulsa, Okla. .... '19
Nevin, Charles M., Cornell University, Geological Dept., Ithaca, N. Y. .... '22
Newby, Jerry B., 1816 N. W. Twenty-Third St., Oklahoma City, Okla. .... '17
Newcombe, Robert J. B., Geological Survey Division, Lansing, Mich. .... '29
||Newell, W. John, United Gas System, Mason Bldg., Houston, Tex. .... '31
||Newland, John B., Neola, Iowa .... '31
Newman, Thomas F., Skelly Oil Co., Geological Dept., Tulsa, Okla. .... '25
Nicholls, William M., 513 City Natl. Bank Bldg., Wichita Falls, Tex. .... '27
||Nichols, Arthur A., 360 Forest Ave., Ambler, Pa. .... '30
Nichols, C. R., Box 2880, Dallas, Tex. .... '20
||Nichols, Paul B., Route 1, Box 27, Fairbanks, Tex. .... '29
Nickell, C. O., 500½ W. Thirty-One and One-half St., Austin, Tex. .... '19
||Nicola, Oliver P., Jr., 2012 W. Cherokee St., Enid, Okla. .... '28
Nightingale, W. T., Mountain Fuel Supply Co., Rock Springs, Wyo. .... '24
Nisbet, John M., 703 Empire Bldg., Bartlesville, Okla. .... '18
Noble, Arthur H., Sarawak Oilfields, Ltd., Miri, Sarawak, via Singapore .... '24
Noble, Earl B., Union Oil Co. of Calif., 1115 Union Oil Bldg., Los Angeles, Calif. .. '24
Noble, Gilbert W., Box 200, Clarksburg, W. Va. .... '26
Noble, Homer A., 1651 Colquitt, Houston, Tex. .... '20
Nolan, Philip E., Venezuela Gulf Oil Co., Maracaibo, Venezuela, S. A. .... '25
Nolte, William J., Stanolind Oil & Gas Co., Medical Arts Bldg., Fort Worth, Tex. .. '23
Nomland, J. O., Standard Oil Bldg., San Francisco, Calif. .... '28
Nordman, O. E., 1308 W. Fir St., Perry, Okla. .... '23
||Norman, M. E., 1405 Gould Ave., Fort Worth Tex., ... '30
North, Lloyd, 2041 Branard Ave., Houston, Tex. .... '22
Norton, George H., Atlantic Oil Prod. Co., 906 Central Bldg., Wichita, Kan. ... '21
||Norton, Richard D., The Texas Co., Box 1737, Shreveport, La. .... '28
Norville, Glen S., Box 1267, Ponca City, Okla. .... '29

Notestein, Frank B., Box 295, Wooster, Ohio ... '20
Nowels, Kenneth B., Forest Oil Corp., Bradford, Pa. ... '23
Nowlan, Harry H., Darby Petr. Co., 5th Floor Philcade Bldg., Tulsa, Okla. ... '21
Nufer, D. C., Box 801, Tulsa, Okla. ... '30
Nuttall, W. L. F., Longfield, Madingley Road, Cambridge, England ... '24
||Nye, S. Spencer, Route 1, Box 67, E. Brownsville, Tex. ... '27

Oakes, Malcolm C., 402 E. Third St., Edmond, Okla. ... '24
||O'Bannon, P. H., 903 Humble Bldg., Houston, Tex. ... '30
Obering, Ernest A., Box 623, Carlsbad, N. Mexico ... '24
Oborne, Harry W., 1428 Wood Ave., Colorado Springs, Colo. ... '23
Oborne, Wilbur A., 11 Park Ave., Babylon, N. Y. ... '28
||O'Brien, Shamus, Florence, Kan. ... '23
Officer, Herbert G., 1755 S. St. Louis St., Tulsa, Okla. ... '22
||Ogier, E. H., 2333 Foster Ave., Ventura, Calif. ... '31
Ohern, D. W., 515 W. Fourteenth St., Oklahoma City, Okla. ... '18
||Ohliger, F. W., Bin XX, Taft, Calif. ... '27
||O'Keeffe, Hugh W., 418 S. Thirteenth St., Fort Smith, Ark. ... '30
Oldham, Albert E., Arkansas Nat. Gas Corp., Shreveport, La. ... '25
Oles, L. M., Prairie Oil & Gas Co., Box 1242, Amarillo, Tex. ... '24
||Oles, Paul S., 505 Hamilton Bldg., Wichita Falls, Tex. ... '25
Oliphant, A. G., 2114 S. Norfolk St., Tulsa, Okla. ... '27
Oliver, Henry M., California-Eastern Oil Co., 986 Pacific Electric Bldg., Los Angeles, Calif. ... '28
Olson, Walter S., Box 200, Baguio, Benquet, P. I. ... '27
Olsson, Axel A., 48 Woodside Ave., Gloversville, N. Y. ... '20
O'Neill, Frank E., 2448 E. Flower St., Huntington Park, Calif. ... '25
*Orcutt, W. W., Union Oil Co., Union Oil Bldg., Los Angeles, Calif. ... '26
Ordoñez, Ezequiel, Abraham Gonzalez 79, Mexico City, Mexico ... '24
Orr, Milo M., Box 191, Laredo, Tex. ... '20
Orynski, Leonard W., The California Co., 17th Floor Petroleum Tower, Dallas, Tex. ... '23
Osborne, Clarence B., 402 Security Bldg., Los Angeles, Calif. ... '21
||Osborne, Paul F., 737 Clayton St., Denver, Colo. ... '30
Osborne, Robert R., 2603 Smith-Young Tower, San Antonio, Tex. ... '23
||Osorio, Gustave A., Apartado 153, Barranquilla, Colombia, S. A. ... '31
Ott, Emil, Box 578, San Angelo, Tex. ... '24
Owen, Edgar W., 1015 Milam Bldg., San Antonio, Tex. ... '19
Owen, H. J., 304 N. Third St., Okemah, Okla. ... '23
||Owen, Kenneth Dale, 320 Eleanor Ave., San Antonio, Tex. ... '27
Owens, Allen L., Trinidad Oilfields Operating Co., Ltd., Box 18, San Fernando, Trinidad, B. W. I. ... '20
Owens, Frith C., Box 548, Laredo, Tex. ... '26
Oyster, Frank A., 1216 Palm St., Abilene, Tex. ... '21

||Pack, Oran L., 726 E. Raleigh, Glendale, Calif. ... '26
Pack, R. W., Drawer 790, Beaumont, Tex. ... '18
Packard, Sidney A., Arkansas Nat. Gas Co., Geological Dept., Shreveport, La. ... '21
Page, James H., Box 871, Tulsa, Okla. ... '25
Paige, Sidney, 2911 Thirty-Third St. N. W., Washington, D. C. ... '21
||Paine, L. E., Box 153, Arcadia, Okla. ... '27
||Palmer, Joe C., 210 Sawes Moore Bldg., Laredo, Tex. ... '29
||Palmer, Katherine V. W., Cornell University, Geological Dept., Ithaca, N. Y. ... '28
Palmer, Robert H., Apartado 10, Matanzas, Cuba ... '23
Panyity, Louis S., 66 Main St., Bradford, Pa. ... '20
Parker, Ben H., 1007 Twelfth St., Golden, Colo. ... '28
Parker, Everett C., 505 N. Bridge St., Victoria, Tex. ... '17
Parker, Robert L., Box 493, Rolla, Mo. ... '27
Parks, Emerson M., Ten Sleep, Wyo. ... '24
Parks, Ernest K., Bin XX, Taft, Calif. ... '25
||Parris, Frank G., Room 3130, 50 W. Broad St., Columbus, Ohio ... '29
Parrish, Gaston H., 1515 Chaparral St., Corpus Christi, Tex. ... '25
||Parsons, Claude P., Halliburton Cementing Co., Duncan, Okla. ... '27

||Paschal, Elisha A., 1011 Tradesmen's Natl. Bank Bldg., Oklahoma City, Okla...'22
Patrick, Walden W., Box 1208, Midland, Tex....'21
Patterson, J. M., Box 359, Lawrence, Kan....'25
||Patterson, Luther Edwin, Jr., 930 W. Fourteenth St., Oklahoma City, Okla....'30
Patterson, Robert D., 405 Haberfelde Bldg., Bakersfield, Calif....'28
Patton, Leroy T., Texas Technological College, Lubbock, Tex....'24
||Patton, Roger R., Box 312, Shawnee, Okla. (Mail returned)....'29
Paul, A. G., (formerly Boghossian), 2231 Seventh Ave., Astoria, N. Y....'26
Paulsen, Jasper W., 721 Bank of Italy Bldg., Los Angeles, Calif. (Mail returned)....'27
Paxson, Roland B., 1857 Lexington St., Houston, Tex....'26
||Payne, Roy A., 728 E. Miami, McAlester, Okla....'29
||Payne, Willard M., Box 867, Clewiston, Fla....'30
Peabody, Harlan W., Box 381, Tulsa, Okla....'19
||Pease, Cecil C., 1259 Buchanan St., Topeka, Kan....'21
Pellekaan, W. Van Holst, Shell Petr. Corp., Shell Bldg., St. Louis, Mo....'21
Pellissier, Andre, Pechelbronn S. A. E. M., Bibliotheque Technique à Merkwiller-Pechelbronn, Strasbourg, France....'25
Pemberton, J. R., 525 N. Palm Drive, Beverly Hills, Calif....'17
Penny, Frederick W., Phoenix Oil & Trans. Co., Casuta Postala No. 1, Ploestia, Roumania....'24
||Pentegoff, Vladimir, 9035 Venice Blvd., Los Angeles, Calif....'28
||Pepper, James F., c/o Mrs. L. M. French, Pulteney, Steuben County, N. Y....'27
Pepperberg, Leon J., First Natl. Bank Bldg., Dallas, Tex....'19
Perini, Vincent C., Jr., Box 886, San Angelo, Tex....'23
Perkins, Joseph M., Box 1055, Eastland, Tex....'19
Perkinson, Floyd, R. F. D. 1, Purcell, Okla....'31
Perrine, Irving, 1619–21 Petroleum Bldg., Oklahoma City, Okla....'17
Perry, Donald C., Lemoore, Kings County, Calif....'32
Peterson, Clarence J., Texoma Nat. Gas Co., 4th Floor Rule Bldg., Amarillo, Tex. '19
Petrascheck, Wilhelm, Geological Museum, Mining Academy, Leoben, Austria....'28
Petsch, Arthur H., Box 318, Laredo, Tex....'20
||Pettigrew, Virgil, Humble Oil & Refg. Co., Box 1034, Wichita Falls, Tex....'25
Petty, Dabney E., 10 Tenth St., San Antonio, Tex....'20
Petty, O. S., 10 Tenth St., San Antonio, Tex....'31
Petty, T. F., Box 400, Cisco, Tex....'29
||Pfaankuche, Kathleen Tarver, 3240 James St., Fort Worth, Tex....'29
Philbrick, E. P., Magnolia Petr. Co., Wichita, Kan....'23
||Phillippi, Paul M., Olean Petr. Co., Box 522, Olean, N. Y....'30
Pike, Ruthven W., Instructed to hold mail....'29
||Pilcher, Ben L., Jr., 2818 Rio Grande, Austin, Tex....'30
||Pinkley, George R., 1201 Alamo Natl. Bldg., San Antonio, Tex....'29
Pirtle, George W., Box 940, Tyler, Tex....'27
Pishel, Max A., 1646 S. Denver St., Tulsa, Okla....'18
Pittman, C. V. A., 1311 Republic Bank Bldg., Dallas, Tex....'32
||Plaster, William M., Meeker, Okla....'29
Plummer, F. B., Bureau of Economic Geology, Univ. of Texas, Austin, Tex....'19
Pogue, Joseph E., 43 Fifth Ave., New York, N. Y....'24
||Poland, Joseph F., Encena Ave., Box 345, Menlo Park, Calif....'31
Ponton, G. M., Florida State Geological Survey, Tallahassee, Fla....'29
Porch, Edwin L., Jr., Box 573, San Antonio, Tex....'20
||Porter, John L., 181 Claremont, Long Beach, Calif....'32
Porter, William W., II, 8315 Beverly Blvd., Los Angeles, Calif....'27
Ports, Waldo W., 1823½ Collins St., Wichita Falls, Tex....'26
||Pospisil, Frank J., Lago Petr. Corp., Apartado 172, Maracaibo, Venezuela, S. A. '29
||Postley, Olive C., The Calverton, Washington, D. C....'26
Potter, Grover C., Box 1177, Beeville, Tex....'22
Potter, Nelson B., c/o J. R. Steele, DeKalb, Mo....'26
Poulin, John A., Sinclair Exploration Co., 45 Nassau St., New York, N. Y....'32
Poulsen, Frank E., 3203 W. Oneal St., Greenville, Tex....'25
Powell, Ralph S., The Texas Co., Wichita Falls, Tex....'27
Power, Harry H., 1543 E. Nineteenth St., Tulsa, Okla....'28
Powers, Delmer, L., Continental Oil Co., 1040 Continental Bldg., Denver, Colo...'29
Pratt, Ernest S., Box 1400, Wichita, Kan....'22

Pratt, Wallace E., Humble Oil & Refg. Co., Houston, Tex. '18
Preece, Rae, 2008 E. Fourteenth St., Tulsa, Okla. '22
Pressler, Edward D., Humble Oil & Refg. Co., Uvalde, Tex. '31
Preston, John Basil, Glasgow, Ky. '28
Prettyman, T. M., 1901 W. T. Waggoner Bldg., Fort Worth, Tex. '24
Price, Sylvan S., 1502 Philtower Bldg., Tulsa, Okla. '17
Price, W. Armstrong, Box 112, Corpus Christi, Tex. '25
Pritchard, George B., 6 Kooyongkoot Road, Hawthorn, Melbourne, Victoria, Australia '25
Prommel, Harald W. C., 731 S. Downing St., Denver, Colo. '22
Prout, F. S., Box 417, Tyler, Tex. '17
||Pryor, George W., 831 Rutherford St., Shreveport, La. '31
||Pugh, William E., Plains Exploration Co., 919 University Bldg., Denver, Colo. '30
Purzer, Joseph, 1620 W. First, Tulsa, Okla. '26
||Putman, Darrell M., Producers & Refiners Corp., First Natl. Bank Bldg., Wichita, Kan. (Mail returned) '30
||Putnam, George D., 809 E. Ninth Ave., Winfield, Kan. '27
||Pyle, Howard C., 1336 S. Westlake Ave., Los Angeles, Calif. '29
Pyle, James R., Box 416, Owensboro, Ky. '20

Quiett, Roy C., Indian Territory Illum. Oil Co., Seminole, Okla. '22
Quilliam, William, 720 Irma Ave., Beaumont, Tex. '26

Radcliffe, Donald H., 5930 Franklin Ave., Hollywood, Calif. '20
Radler, Dolly, Drawer 2040, Tulsa, Okla. '21
Rae, Colin C., Skelly Oil Co., Tulsa, Okla. '19
Ragsdale, Thomas M., Magnolia Petr. Co., Box 971, Oklahoma City, Okla. '31
Ralston, Wallace, Box 807, Tyler, Tex. '23
Rank, Raymond A., 1516 Coty, Shreveport, La. '26
||Rankin, Charles H., Jr., 1042 Continental Oil Bldg., Denver, Colo. '31
Rankin, Charles L., Humble Oil & Refg. Co., 518 Weber Bldg., Lake Charles, La. '27
||Rankin, Horace Ellis, Box 1650, Dallas, Tex. (Mail returned) '31
Rankin, Wilbur D., 1325 Opechee Way, Glendale, Calif. '27
Rath, Charles M., 1254 Cook St., Denver, Colo. '23
Rathwell, Harold B., Box 104, Beverly Hills, Calif. '25
Rau, Harold L., Carter Oil Co., Seminole, Okla. '25
Rau, William M., 929 American, Long Beach, Calif. '28
Rauch, Wayne C., Superior Oil Co. of Calif., 1104 Tower Petroleum Bldg., Dallas, Tex. '27
Ray, W. C., 224 W. Beauregard Ave., San Angelo, Tex. '29
Rea, Henry C., 2307 Prince St., Berkeley, Calif. '29
Rea, John E., Hot Springs, N. Mexico '29
||Reagan, Paul H., 1741 E. Fourth St., Tucson, Ariz. '28
Redfield, John S., Shell Petr. Corp., Box 1191, Tulsa, Okla. '27
Redmon, Harold E., 1924 S. Wheeling, Tulsa, Okla. '30
||Reed, Edwin M., 1729 S. Evanston, Tulsa, Okla. '27
Reed, Eugene C., 1316 S. Twenty-Fourth St., Lincoln, Neb. '28
Reed, Lyman C., Bryan, Tex. '22
Reed, Ralph D., 1110 Glendon Way, S. Pasadena, Calif. '20
||Reed, Warren B., 731 Royal St., New Orleans, La. '22
Reeds, A. C., 1123 W. Fortieth St., Oklahoma City, Okla. '19
Reese, Donald M., Box 908, Tyler, Tex. '30
Reese, Richard G., 631 S. Greenleaf Ave., Whittier, Calif. '27
Reeside, John Bernard, Jr., Box 175, Hyattsville, Md. '26
Reeves, John R., 133 W. Gray St., Elmira, N. Y. '24
||Regan, John H., 115 E. Koenig, Grand Island, Neb. '30
Reger, David B., Box 816, Morgantown, W. Va. '19
||Reiche, Parry, 203 Professional Bldg., Long Beach, Calif. '28
Reid, Robert P., Empire Gas & Fuel Co., Bartlesville, Okla. '27
||Reid, William, Jr., 1410 McGowen Ave., Houston, Tex. '31
||Reiff, Allan, Pawnee City, Neb. (Mail returned) '30
Reisher, Paul H., Box 661, Tulsa, Okla. '21
Reiter, Wilhelm A., Box 856, Mexia, Tex. '22

Remington, Arthur E., Pure Oil Co., 1140 Subway Terminal Bldg., Los Angeles, Calif. '25
Renaud, Charles L., 1901 W. T. Waggoner Bldg., Fort Worth, Tex. '23
Renick, B. Coleman, 2110 Alamo Natl. Bldg., San Antonio, Tex. '25
Rennie, Waldo E., 1520 Steele St., Denver, Colo. '25
Requa, Lawrence K., Mills Bldg., San Francisco, Calif. '28
Rettger, Robert E., 133 N. Woodlawn Ave., San Antonio, Tex. '25
Reynolds, R. Eugene, Box 417, Tyler, Tex. '25
Reynolds, Roy A., 2835 Fifth Ave., Fort Worth, Tex. '19
Rhine, Elton, Box 956, Houston, Tex. '23
Rhoades, Ralph O., 109 S. McGregor St., Carthage, Mo. '24
Rhoades, Roy S., 1311 Edwards & Wildey Bldg., Los Angeles, Calif. '23
‖Rhodes, Edward J, 45 Thornton St., Wollaston, Mass. '31
Ribble, John M., 1523 N. W. Thirty-Sixth St., Oklahoma City, Okla. '31
‖Rice, Elmer M., Box 22 J, Van, Tex. '27
Rich, John L., Univ. of Cincinnati, Geological Dept., Cincinnati, Ohio '19
Richards, J. T., 901 Petroleum Bldg., Oklahoma City, Okla. '24
Richards, Ralph W., 2717 Connecticut Ave. N. W., Washington, D. C. '19
Richards, Raymond, 17 Battery Place, New York, N. Y. '25
‖Richardson, H. T., Box 96, Cuero, Tex. '30
Richardson, R. K., Anglo Persian Oil Co., Ltd., Britannic House, Finsbury Circus, London, E. C. 2, England '29
‖Richmond, Wallace E., Jr., 292 South Ave., Bradford, Pa. '27
Rider, Charles R., Apartado 223, Maracaibo, Venezuela, S. A. '20
Ridgeway, Bertrand S., 206 S. Fourteenth St., Independence, Kan. '21
Ridings, Lowell J., 1616 W. Twenty-Third St., Oklahoma City, Okla. '25
Ries, Heinrich, Cornell University, Geological Dept., Ithaca, N. Y. '26
‖Ries, Minette, Phillips Petr. Co., San Angelo, Tex. '30
Rife, Byron, 923 Neil P. Anderson Bldg., Fort Worth, Tex. '23
‖Riggs, Calvin H., Box 34, Muskegon, Mich. '32
Riggs, Robert J., Drawer L., Bartlesville, Okla. '17
Ring, Dewitt T., Ohio Fuel Gas Co., Box 1274, Columbus, Ohio '20
Riter, Samuel W., Box 661, Tulsa, Okla. '26
Ritter, Ernest A., Cia. Mex. de Petr. "El Aguila," S. A., Tampico, Mexico '30
Rixleben, Bruno, Box 565, Holdenville, Okla. '27
Roark, Edward L., Jarvis & Holm, Inc., 1037 Kennedy Bldg., Tulsa, Okla. '22
Roark, Louis, 2652 S. Trenton, Tulsa, Okla. '19
Roark, R. B., Shell Petr. Corp., Box 1191, Tulsa, Okla. '21
Robbins, C. C., 1710 Union Bank Bldg., Pittsburgh, Pa. '24
Roberts, Dwight C., 2000 W. Twelfth St., Los Angeles, Calif. '25
Roberts, John R., 600 Sheldon Bldg., San Francisco, Calif. '19
Roberts, Louis C., Jr., Box 924, Fort Worth, Tex. '25
Roberts, Morgan E., Box 637, Odessa, Tex. '20
Robertson, Glenn D., 2826 S. Norton Ave., Los Angeles, Calif. '26
Robertson, Parker A., Box 968, Midland, Tex. '23
Robinson, B. F., 709 E. Thirteenth St., Cameron, Tex. '21
Robinson, Cecil D., Box 237, Fort Smith, Ark. '28
Robinson, Ernest Guy, Shell Petr. Corp., Drawer 15, St. Louis, Mo. '22
Robinson, Heath M., 810 Tower Petroleum Bldg., Dallas, Tex. '22
Robinson, J. French, 545 William Penn Way, Pittsburgh, Pa. '20
Robinson, W. I., Texas Technological College, Geological Dept., Lubbock, Tex. '22
Rogatz, Henry, 124 E. Eighty-Fourth St., New York, N. Y. '25
Rogers, Ola J., Cleveland, Okla. '19
Rogers, Reese F., Monteagle, Tenn. '20
Rohwer, F. W., 505 Sunderland Ave., Calgary, Alta., Canada '24
‖Rolhausen, F. W., 903 Humble Bldg., Houston, Tex. '28
Rollin, George S., 2518 E. Twenty-Seventh St., Tulsa, Okla. '21
Romine, Thomas B., Box 1868, Fort Worth, Tex. '23
Roop, Charles W., 3551 E. Douglas, Wichita, Kan. '22
Rosaire, Carol G., 2110 Esperson Bldg., Houston, Tex. '31
Rosaire, E. E., 2210 Esperson Bldg., Houston, Tex. '31
Roschen, Ernest C. H., Cherry Hill Lane, Reisterstown, Md. '29
Rose, Harrison W., 1514 Petroleum Bldg., Houston, Tex. '30

Rosenthal, Bernard, Box 126, Mexico, Mo. '28
||Ross, Charles M., Geophysical Research Corp., Drawer 2040, Tulsa, Okla. '29
Ross, Clarence S., U. S. Geological Survey, Washington, D. C. '19
Ross, John C., 1923 S. Wheeling, Tulsa, Okla. '21
Ross, John S., 561 Middlefield Road, Palo Alto, Calif. '24
||Rossebo, C. B., 316 "F" S. W., Ardmore, Okla. '27
||Roth, Ernest E., 513 S. Braddock Ave., Pittsburgh, Pa. '21
Roth, Robert, Paonia, Colo. '29
Rothrock, E. P., 111 N. Pine St., Vermillion, S. Dakota '19
Rothrock, Howard E., 1801 W. Easton Court, Tulsa, Okla. '21
Roundy, P. V., U. S. Geological Survey, Washington, D. C. '19
Rousselot, Norman A., 1709 W. Eighth St., Los Angeles, Calif. '27
Row, Charles H., 1029 Milam Bldg., San Antonio, Tex. '19
Rowland, W. Boyd, Romano-Americana, Teleajen-Ploesti, Roumania '26
Ruby, Glen M., 2986 Edmonton Road, Chevy Chase, Glendale, Calif. '22
Ruedemann, Paul, Beethovenplatz 2/5, Vienna, I, Austria '21
||Rumsey, Edward W., 821 Exchange Natl. Bank Bldg., Tulsa, Okla. '30
Rusk, Willard W., 2207 Hayden St., Amarillo, Tex. '26
Russ, Leon F., 3606 Princeton Ave., Dallas, Tex. '19
Russell, C. A., 18th Floor Petroleum Bldg., Houston, Tex. '29
Russell, F. E., Throckmorton, Tex. '30
||Russell, Hewlett A., 513 Williams St., Tyler, Tex. (Mail returned) '29
||Russell, J. J., Jr., Merkel, Tex. '29
Russell, Philip G., Box 635, Eastland, Tex. '21
Russell, William L., 430 Temple St., New Haven, Conn. '24
Russom, Vaughn W., Box 767, Fort Worth, Tex. '21
Rutledge, R. B., Box 2087, Tulsa, Okla. '26
Ryan, Reginald G., Laredo, Tex. '23
Ryan, Russell F., 512 McGowen Ave., Houston, Tex. '26
Ryniker, Charles, Box 661, Tulsa, Okla. '25

Sackett, H. F., 503 Kennedy Bldg., Tulsa, Okla. '27
Salvatori, Henry, 1311 Republic Bank Bldg., Dallas, Tex. '30
Sammons, George B., Natoma, Kan. '24
Samuell, J. Howard, Box 652, Coleman, Tex. (Mail returned) '26
Sanders, C. W., Jr., Box 1651, Amarillo, Tex. '27
Sanderson, James O. G., Box 134, Turner Valley, Alta., Canada '28
Sandidge, John R., Princeton University, Geological Dept., Princeton, N. J. '29
Sands, J. M., Phillips Petr. Co., Bartlesville, Okla. '17
||Sanford, D. H., 2432 E. First St., Duluth, Minn. '30
||Sappington, Chester, Room 10, Weston Bldg., Ardmore, Okla. (Mail returned) '28
||Sargent, E. C., Bureau of Economic Geology, Austin, Tex. '30
Sasse, Jerome B., Shell Petr. Corp., Box 2099, Houston, Tex. '29
Saville, Wilson G., 903 Branard, Houston, Tex. '29
Sawtelle, George, Kirby Petr. Co., Houston, Tex. '22
Sawyer, Roger W., 1616 S. Seventeenth St., Chickasha, Okla. '20
Sawyer, Theodore K., 1432½ Micheltorena, Los Angeles, Calif. '28
||Sax, Henry, Ard. Pauwstr. 19, den Haag, Holland '26
Say, Stanley R., Apartado 269, Monterrey, N. L., Mexico '25
||Sayre, J. E., 1921 Broadway, Shawnee, Okla. '29
||Schaeffer, Hugh C., 3416 N. W. Twentieth St., Oklahoma City, Okla. '26
||Schell, Fred A., Jr., 1503 S. Knoxville, Tulsa, Okla. '29
||Schenck, Francis R., 832 Bowie, Amarillo, Tex. '32
Schider, Rodolphe, Cia. Mex. de Petr. "El Aguila," Apartado 150, Tampico, Mexico '28
||Schillhahn, E. O., 800 Union Trust Bldg., Springfield, Ohio (Mail returned) '31
Schilling, Karl H., Box 439, Muskegon, Mich. '23
Schlosser, Paul A., Box 816, San Angelo, Tex. '23
Schlumberger, Conrad, Prospection Electrique, 40 Rue Fabert, Paris, VII^e, France '31
Schmidt, Karl A., Tidal Oil Co., W. T. Waggoner Bldg., Fort Worth, Tex. '25
||Schmotzer, J. W., 124 E. Jordan St., Shreveport, La. '31
Schneider, G. W., Box 1737, Shreveport, La. '25
Schneider, Henry G., 112 E. Twenty-Seventh St., Tulsa, Okla. '23

Schnurr, Cornelius, 2306 Kingston Drive, Houston, Tex. . . . . '22
Schoeneck, Philip S., Atlantic Oil Prod. Co., 806 Magnolia Bldg., Dallas, Tex. . . . . '21
Scholl, Louis A., Jr., 605 Harold St., Houston, Tex. . . . . '19
‖Schon, Otto, Baba-Gurgur, Kirkuk, Iraq . . . . . '31
Schoolfield, R. F., 2121 Alamo Natl. Bldg., San Antonio, Tex . . . . . '21
Schouten, Franklin H., 115 E. Berta St., Tyler, Tex. . . . . '26
Schramm, E. F., Morrill Hall, Univ. of Nebraska, Lincoln, Neb. . . . . '19
Schuchert, Charles, Yale University, New Haven, Conn. . . . . '19
Schumacher, J. P., 1028 Post Dispatch Bldg., Houston, Tex. . . . . '24
Schürmann, H. M. E., van voorschotenlaan 2, The Hague, Holland . . . . . '31
Schwabrow, John R., U. S. Geological Survey, Federal Bldg., Casper, Wyo. . . . . '27
Schwartz, H. E., Box 56, Kingsmill, Tex. . . . . '30
Schwarz, Melbert E., Box 65, Geismar, La. . . . . '25
‖Schweer, Henry F., Box 225, Demopolis, Ala. (Mail returned) . . . . . '28
Schwennesen, Alvin T., Box 877, Houston, Tex. . . . . '25
Sclater, Kenneth C., 1336 E. Nineteenth St., Tulsa, Okla. . . . . '26
Scott, Gayle, Texas Christian University, Fort Worth, Tex. . . . . '21
Scott, H. M., 533 Beacon Life Bldg., Tulsa, Okla. . . . . '21
‖Scott, Horace L., 610–12 Ellis Singleton Bldg., Wichita, Kan. . . . . '28
‖Scott, Vernon C., The Texas Prod. Co., Box 2100, Denver, Colo. . . . . '31
Scruggs, Maurice D., Continental Oil Co., Box 1267, Ponca City, Okla. . . . . '26
Scudder, Ernest W., Box 2097, Denver, Colo. . . . . '17
‖Seale, Robert I., 1313 Petroleum Bldg., Houston, Tex. . . . . '31
Sealey, Fred C., The Texas Co., Box 2332, Houston, Tex. . . . . '20
Seaman, L. O., Sinclair Oil & Gas Co., Box 739, Tyler, Tex. . . . . '28
‖Searight, Walter V., 24 N. Yale St., Vermillion, S. Dakota . . . . . '32
Sears, Julian D., 209 E. Underwood St., Chevy Chase, Md. . . . . '24
Seashore, Paul T., 1112 Whitney Bldg., New Orelans, La. . . . . '27
‖Secor, Dana M., R. F. D. 6, Trenton, N. J. . . . . '28
‖Seevers, Harris N., 1713 Third St., Corpus Christi, Tex. . . . . '27
‖Seifert, Wilbur H., 639 Oakland Ave., Greensburg, Pa. . . . . '32
Seitz, J. R., 532 Waggoner Bldg., Wichita Falls, Tex. . . . . '24
‖Self, Selden R., Box 832, San Angelo, Tex. . . . . '29
Selig, A. L., 2432 Shirley Ave., Fort Worth, Tex. . . . . '23
Sellards, E. H., Bureau of Economic Geology, Univ. of Texas, Austin, Tex. . . . . '19
Semmes, Douglas R., 1601 Milam Bldg., San Antonio, Tex. . . . . '19
Senftleben, Gerhard G., 10704 Normandie, Los Angeles, Calif. . . . . '27
Severson, George A., Escritorio 724, 229 Calle Florida, Buenos Aires, Argentina, S. A. . . . . '26
Severy, C. L., 816 Kennedy Bldg., Tulsa, Okla. . . . . '17
Seymour, D. Bruce, Continental Oil Co., 417 S. Hill St., Los Angeles, Calif. . . . . '28
Shakely, Ed., Shell Petr. Corp., Shell Bldg., St. Louis, Mo. . . . . '25
‖Shamblin, William E., Box 296, Holdenville, Okla. . . . . '27
Shaub, Benjamin M., 16 Paradise Road, Northampton, Mass. . . . . '32
Shaw, E. Wesley, Iraq Petr. Co., Ltd., City Gate House, Finsbury Square, London, E. C. 2, England . . . . . '18
Shaw, Everett S., Box 240, Denver, Colo. . . . . '22
‖Shay, D. C., 2008 Parker St., Berkeley, Calif. . . . . '30
Shayes, Fred P., United Prod. Corp., Beeville, Tex. . . . . '23
Shea, E. F., 2207 E. Twentieth St., Tulsa, Okla. . . . . '21
Shearer, Harold K., Box 532, Shreveport, La. . . . . '20
Sheldon, Israel R., 2605 Smith-Young Tower, San Antonio, Tex. . . . . '21
Sheldon, William W., 907 Milam Bldg., San Antonio, Tex. . . . . '24
Shelton, George H., 1704 Milam Bldg., San Antonio, Tex. . . . . '27
‖Shelton, T. O'D., 1118 City Central Natl Bank Bldg., San Antonio, Tex. . . . . '26
Shepard, Edward M., 1403 Benton Ave., Springfield, Mo. . . . . '19
Sheppard, George, 3 Village Road, Garden Village, Hull, England . . . . . '27
Sherman, Richard W., 714 W. Tenth St., Room 918, Los Angeles, Calif. . . . . '28
Sherman, Roger H., Apartado 94, Tampico, Tamps., Mexico . . . . . '32
Sherrill, Richard E., 105 Highland Place, Ithaca, N. Y. . . . . '27
Sherry, William J., 841 Kennedy Bldg., Tulsa, Okla. . . . . '27
Shiarella, Nicholas W., 619 Frederica St., Owensboro, Ky. . . . . '22
Shoenfelt, C. E., 401 Continental Oil Bldg., Denver, Colo. . . . . '28

Show, Joseph H., Box 915, Coalinga, Calif. .... '27
Shuler, Ellis W., Southern Methodist University, Dallas, Tex. .... '19
Shutt, Roscoe E., Shell Petr. Corp., Box 1191, Tulsa, Okla. .... '23
Sickler, Jack M., 734 Pacific Mutual Bldg., Los Angeles, Calif. .... '19
Sidwell, Carroll V., Box 902, Seminole, Okla. .... '22
Sidwell, Raymond, Texas Technological College, Geological Dept., Lubbock, Tex. .... '28
||Siegfus, Stanley S., Box 35, Coalinga, Calif. .... '28
||Simmons, Kenneth A., 1406 Rosewood, San Antonio, Tex. .... '29
Simmons, Rouse, 418 Bartlett Bldg., Los Angeles, Calif. .... '26
Simonds, Frederic W., Univ. of Texas, Austin, Tex. .... '20
||Simonton, Owen W., 886 E. Broad St., Columbus, Ohio .... '31
||Simpson, Richard W., Jr., Ada, Okla. .... '30
Singewald, Joseph T., Jr., 17 W. Twenty-Ninth St., Baltimore, Md. .... '21
Singewald, Quentin D., Univ. of Rochester, Rochester, N. Y. .... '27
Sisler, James D., Box 879, Morgantown, W. Va. .... '31
Siverson, G. C., 3439 Eleventh Ave. S., Minneapolis, Minn. .... '27
Skirvin, Orren W., Skirvin Hotel, Oklahoma City, Okla. .... '21
Slipper, S. E., 215 Sixth Avenue W., Calgary, Alta,. Canada .... '23
Small, Walt M., Cooperstown, Pa. .... '17
Smalley, Claire F., 722 N. Eighth St., Duncan, Okla. .... '31
||Smedley, Harold O., 123 S. Twenty-Eighth St., Lincoln, Neb. .... '28
Smiley, H. F., 704 Hamilton Bldg., Wichita Falls, Tex. .... '23
Smirnoff, Michael A., Southern Crude Oil Purch. Co., 516 Milam Bldg., San Antonio, Tex. .... '26
||Smiser, Jerome S., 23 William St., Princeton, N. J. .... '30
Smith, A. E., Shell Petr. Corp., Box 2099, Houston, Tex. .... '31
||Smith, Colin Hubbard, 2082 S. Harvard Blvd., Los Angeles, Calif. .... '31
||Smith, Erwin W., 2303 Esperson Bldg., Houston, Tex. .... '24
||Smith, Floyd C., 501 N. Creek, Holdenville, Okla. .... '30
Smith, Gene R., Baker Hotel, Dallas, Tex. (Mail returned) .... '26
Smith, George J., 550 Bowd in St., Palo Alto, Calif. .... '27
*Smith, George Otis, Federal Power Commission, Interior Bldg., Washington, D. C. .... '26
||Smith, Gerald N., 120 S. E. Forty-Third St., Oklahoma City, Okla. .... '27
||Smith, Hampton, 248 E. Orange Ave., Monrovia, Calif. .... '30
||Smith, Julian W., Box 1116, Enid, Okla. .... '30
||Smith, Lee C., 2611 Smith-Young Tower, San Antonio, Tex. .... '31
Smith, Lloyd B., 2617 Dillard St., Shreveport, La. .... '20
||Smith, Luther B., Jr., 427 W. Front, Tyler, Tex. .... '30
Smith, Merritt B., Box 148, Palo Alto, Calif. .... '22
||Smith, R. K., Route 6, Box 9, Fort Worth, Tex. .... '30
Smith, Richard A., Geological Survey Division, State Office Bldg., Lansing, Mich. .... '22
Smith, Robert H., 513 Williams Court, Tyler, Tex. .... '27
||Smith, Rufus M., 428 S. Quincy, Kansas City, Mo. .... '29
Smith, Wayne M., 729 Truxtun Ave., Bakersfield, Calif. .... '28
Snider, George W., 228 Belvidere Drive, San Antonio, Tex. .... '24
Snider, L. B., 319 Parland Place, San Antonio, Tex. .... '19
Snider, L. C., Henry L. Doherty & Co., 60 Wall St., New York, N. Y. .... '18
Snively, H. Norman, Box 2446, Denver, Colo. .... '23
Snow, D. R., Box 2039, Tulsa, Okla. .... '20
Snyder, John Y., 1211 City Bank Bldg., Shreveport, La. .... '20
Solliday, A. L., Box 591, Tulsa, Okla. .... '22
Somers, Ransom E., The Gulf Cos., Gulf Bldg., Pittsburgh, Pa. .... '19
Soper, E. K., 845 Muirfield Road, Los Angeles, Calif. .... '25
Soper, Ralph H., Standard Oil Co., (Ind.), 910 S. Michigan Ave., Chicago, Ill. .... '31
Sorenson, I. L., Humble Oil & Refg. Co., Kilgore, Tex. .... '31
Souther, John B., 239 Luther Drive, San Antonio, Tex. .... '24
Soyster, Merwin H., 516 S. Mayo St., Compton, Calif. .... '27
Spangler, Grant W., Box 703, Chickasha, Okla. (Mail returned) .... '25
Sparks, Dale Darrell, 4151 Normal Ave., Hollywood, Calif. .... '27
||Spaulding, Ralph V., Drawer 2040, Tulsa, Okla. .... '29
Spears, Walter H., United Gas System, Box 1760, Houston, Tex. .... '28
||Speed, C. D., Jr., Box 933, Corsicana, Tex. .... '30

||Spencer, Lawrence P., Tri-State Gas & Elec. Corp., Elmira, N. Y. '30
||Spencer, Leslie C., Box 312, Shawnee, Okla. '29
||Spencer, Maria, 502 Oklahoma Savings Bldg., Oklahoma City, Okla. '30
Spice, William H., Jr., 2117 Alamo Natl. Bldg., San Antonio, Tex. '24
Spieker, Edmund M., Ohio State University, Geological Dept., Columbus, Ohio. '23
||Splane, Howard Scott, Box 1379, Tulsa, Okla. '25
Spofford, Howard N., 3427 Beverly Place, Shreveport, La. '24
Spooner, W. C., Box 1195, Shreveport, La. '18
Spoor, Harry C., Jr., United Prod. Corp., Box 1760, Houston, Tex. '28
Sprague, William B., The Texas Co., Houston, Tex. '24
||Spratt, J. G., Dept. of Lands and Mines, Administration Bldg., Edmonton, Alta., Canada '30
Sprowls, Harlan A., 423 La Plante Bldg., Vincennes, Ind. '27
Stacy, Dean M., 2821 First Natl. Bank Bldg., Oklahoma City, Okla. '17
Staehelin, Peter Karl, C. M. P. El Aguila S. A., Apartado 86, Puerto Mexico, Ver., Mexico '30
Stafford, Clare J., Darby Petr. Corp., 802 Ellis-Singleton Bldg., Wichita, Kan. '27
||Stafford, Gerald M., 231 Travis St., Kerrville, Tex. '31
||Staggs, Olan B., 802 W. Main St., Enid, Okla. '20
Stainbrook, Merrill A., Texas Technological College, Lubbock, Tex. '29
Stalder, Walter, 925 Crocker Bldg., San Francisco, Calif. '22
Staley, C. G., Proration Office, Hobbs, N. Mexico '30
||Stamey, Roderick A., Mt. Belvieu, Tex. '31
Stander, Arthur E., 1241 S. Frankfort, Tulsa, Okla. '20
||Stangl, Frank J., Jr., Milam Bldg., San Antonio, Tex. '27
Starke, Eric A., 704 S. Spring St., Los Angeles, Calif. '26
Stathers, Silas C., 65 S. Florida St., Buckhannon, W. Va. '19
Stauffer, Clinton R., 107 Pillsbury Hall, Univ. of Minnesota, Minneapolis, Minn. '19
Stauft, J. Lauer, International Petr. Co., Negritos, Peru, S. A. '26
St. Clair, Stuart, 420 Lexington Ave., New York, N. Y. '19
St. Germain, R. J., 804 Wright Bldg., Tulsa, Okla. '26
Stearn, Noel H., 2101 Missouri Pacific Bldg., St. Louis, Mo. '29
||Stebbins, Paul M., 2614 E. Second St., Wichita, Kan. '29
Stebinger, Eugene, General Ballivian FCCNA, Argentina, S. A. '20
||Steel, Robert J., Apt. A, 1302 N. Broadway, Santa Ana, Calif. '31
Stehr, Raymond A., 305 Citizens Natl. Bank Bldg., Tyler, Tex. '28
Steig, Maynard H., Houston Oil Co. of Texas, Box 1779, Houston, Tex. '28
Stein, Ira H., Box 1401, Amarillo, Tex. '23
Steinberger, Clark R., 1301 Frederica St., Owensboro, Ky. '28
Steineke, Max, Route 1, Box 391, Los Altos, Calif. '28
Steinmayer, R. A., Tulane University, New Orleans, La. '20
Steiny, Homer J., Associated Oil Co., 736 Pacific Electric Bldg., Los Angeles, Calif. '25
Stepanoff, Alexander, 716 Petroleum Bldg., Oklahoma City, Okla. (Mail returned) '27
||Stephano, Constantine S., 1014-16 Walnut St., Philadelphia, Pa. '25
||Stephens, Clayton W., Box 217, Venice, Calif. '29
Stephenson, Cuthbert D., 709 Alexander Bldg., Tulsa, Okla. '22
Stephenson, Eugene A., Missouri School of Mines, Rolla, Mo. '19
Stephenson, Lloyd W., 3421 Lowell St., Washington, D. C. '25
Sterrett, Douglas B., Box 150, Kamloops, B. C., Canada '25
Steubing, W. C., 513 Natl. Bank of Commerce Bldg., San Antonio, Tex. '20
Stevens, George D., Box 476, Tyler, Tex. (Mail returned) '30
Stevens, George R., 324 Washington Ave., Shreveport, La. '19
Stewart, Charles A., 141 N. Drive, San Antonio, Tex. '27
||Stewart, Charles H., 2907 Truxillo, Houston, Tex. (Mail returned) '25
Stewart, Hugh A., 612 Gaylord St., Denver, Colo. '23
Stewart, Irvine E., 548 Subway Terminal Bldg., Los Angeles, Calif. '18
Stewart, R. E., Box 745, Ventura, Calif. '28
||Stewart, Robert J. G., 1018 N. Eleventh St., Temple, Tex. '28
Stiles, Edmund B., 802 E. Main St., Mexia, Tex. '20
Stiles, Edward Bryan, 809 E. Maple, Cushing, Okla. '30
Stiles, Elisabeth, 705 E. Nineteenth St., Houston, Tex. '27
Still, J. T., 508 S. Spring St., Tyler, Tex. '31
Stille, Hans, Geological Institute, Univ. of Berlin, Berlin, Germany '31

Stiller, Ernest A., Box 1734, Shreveport, La. .... '27
Stilley, Earl M., 1016 Staley Bldg., Wichita Falls, Tex. .... '22
||Stillman, Francis B., 2996 S. Twenty-Third St. E., Salt Lake City, Utah .... '28
Stipek, Raymond J., 1271 Fillmore St., Topeka, Kan. .... '29
Stipp, Thomas F., 1145 Webster St., Palo Alto, Calif. .... '23
||Stirtz, W. Melvin, Drawer L, Bartlesville, Okla. .... '28
Stockton, Frank R., 1429 Hillcrest Ave., Glendale, Calif. .... '28
Stolz, H. P., 719 Security Bldg., 510 S. Spring St., Los Angeles, Calif. .... '28
Stone, Jefferson A., Glencairn Apts., Bellingham, Wash. .... '27
||Stoner, O. E., 412 Tuloma Bldg., Tulsa, Okla. .... '28
Stoner, R. C., Standard Oil Co., 225 Bush St., San Francisco, Calif. .... '21
Storm, Lynn W., 2107 Neches St., Austin, Tex. .... '25
Storm, Willis, 2146 W. Summit Ave., San Antonio, Tex. .... '20
Strachan, Clarice Bowers, 1320 Arkansas Ave., Durmont, Pittsburgh, Pa. .... '31
Strachan, Clyde G., The Gulf Cos., Gulf Bldg., Pittsburgh, Pa. .... '29
Straub, Charles E., 724 S. Holyoke, Wichita, Kan. .... '21
Streeter, Irving McKay, Aparatado 234, Maracaibo, Venezuela, S. A. .... '30
||Striker, Arthur F., 612 E. Hurd St., Edmond, Okla. .... '26
||Strode, Mack, 1700 Avenue C, Dodge City, Kan. .... '29
Stryker, William L., Fredonia, Kan. .... '25
||Stubbs, John T., 1100 Clarkson, Denver, Colo. .... '26
||Stuckey, William L., 1941 J St., Lincoln, Neb. .... '30
||Stucky, Zenas E., Box 312, Shawnee, Okla. .... '30
Studt, Charles W., Union Gas Corp., Independence, Kan. .... '20
Stutzer, Otto, Saxony Mining School, Freiberg, Saxony, Germany .... '25
Suman, George O., Jr., Associated Oil Co., Oil Center, Calif. .... '21
Suman, John R., 919 Humble Bldg., Houston, Tex. .... '19
Sundberg, Karl, Wahrendorffsgatan 1, Stockholm, Sweden .... '29
Sundt, O. F., Gulf Prod. Co., Drawer C, Houston, Tex. .... '29
Sutton, Chase E., Pure Oil Co., 2208 Esperson Bldg., Houston, Tex. .... '27
Sutton, Frederick A., Room 719, Edificio Banco Boston, Buenos Aires, Argentina, S. A. .... '24
Suverkrop, Lew, 151 H St., Bakersfield, Calif. .... '27
Swigart, T. E., Shell Petr. Corp., Box 2099, Houston, Tex. .... '20
Swiger, Rual B., Box 1069, Beeville, Tex. .... '25
Swindell, Floyd L., 913 Hunt Bldg., Tulsa, Okla. .... '31
Swisher, William Z., 803 N. Walnut, Pauls Valley, Okla. .... '29

||Tabor, Lawrence L., 314 Panoramic Way, Berkeley, Calif. .... '28
||Taegel, Edwin A., 1501 Galveston St., Laredo, Tex. .... '31
Taff, Joseph A., Associated Oil Co., 79 New Montgomery St., San Francisco, Calif. '19
Takahashi, Jun-ichi R., Inst. of Petrology, Imperial University, Sendai, Japan .... '23
Talbott, W. G., 732 N. E. Twenty-First St., Oklahoma City, Okla. .... '32
Taliaferro, Nicholas L., Bacon Hall, Univ. of California, Berkeley, Calif. .... '23
||Tallman, Frank P., Box 281, Coudersport, Pa. .... '29
Tandy, J. Hiram, R. R. 11, Tulsa, Okla. .... '26
Tanner, Hugh A., 117 E. Broadway, Winchester, Ky. .... '27
Tappolet, W., Apartado 31, Puerto Mexico, Ver., Mexico .... '25
Tarr, Russell S., 504 Philtower Bldg., Tulsa, Okla. .... '20
Tarr, W. A., 704 Westwood Ave., Columbia, Mo. .... '27
||Tarragona, Jose, Yacimientos Petroliferos Fiscales, Division Geologia, Paseo Colon 922, Buenos Aires, Argentina, S. A. .... '31
||Tatum, Emmett P., Jr., 903 Humble Bldg., Houston, Tex. .... '29
Tatum, James L., Apartado 209, Monterrey, N. L., Mexico .... '20
Taylor, Charles H., 701 Braniff Bldg., Oklahoma City, Okla. .... '17
Taylor, Cyril B., 3624 Watonga Road, Fort Worth, Tex. .... '25
Taylor, Dewitt E., 405 Haberfelde Bldg., Bakersfield, Calif. .... '28
||Taylor, Garvin L., 664 N. Pershing, Wichita, Kan. .... '30
Taylor, H. Gordon, Box 1225, Little Rock, Ark. (Mail returned) .... '30
||Taylor, Russell W., Box 558, Wichita, Kan. .... '29
||Taylor, Vernon, 119 Sixth Ave. W., Calgary, Alta., Canada .... '31
||Taylor, W. Harlan, 315 W. Seventeenth St., Oklahoma City, Okla. .... '30
||Teagle, John, Humble Oil & Refg. Co., Box 1084, San Antonio, Tex. .... '31

Teas, L. P., Humble Oil & Refg. Co., Houston, Tex. .... '21
Teas, Paul C., 447 Donaldson St., San Antonio, Tex. .... '22
||Teis, Maurice, Parkville, Mo. .... '30
Templeton, James B., 1215 Court St., Muskogee, Okla. .... '25
Templeton, James Clark, International Geophysical Prosp. Co., Ltd., 10–12 Copthall Ave., London, E. C. 2, England .... '26
TenEyck, Warren E., 4041 Pacific Ave., Long Beach, Calif. .... '32
Terrill, John V., Box 1428, Amarillo, Tex. .... '28
Tester, Allen C., Univ. of Iowa, Geological Dept., Iowa City, Iowa .... '21
||Thacher, John H., Jr., Bin XX, Taft, Calif. .... '31
Thalmann, Hans E., N. V. de Bataafsche Petr. Mij., Pangkalan Brandan, Sumatra, D. E. I. .... '27
||Theisen, K. Elizabeth, 420 Memorial Drive, Cambridge, Mass. .... '30
Thom, W. T., Jr., Princeton University, Geological Dept., Princeton, N. J. .... '22
Thomas, C. R., 2616 S. Troost, Tulsa, Okla. .... '20
Thomas, George Dewey, Box 1293, Shreveport, La. .... '27
Thomas, G. Gordon, Fir Tree Cottage, Rodborough Stroud, Gloucestershire, England .... '26
Thomas, Harold S., 2841 W. Twenty-First St., Oklahoma City, Okla. .... '32
Thomas, J. Elmer, 165 Broadway, New York, N. Y. .... '17
||Thomas, Leonard C., Univ. of Iowa, Geological Dept., Iowa City, Iowa .... '30
Thomas, Norman L., Pure Oil Co., Box 1007, Fort Worth, Tex. .... '26
Thomas, William A., Pure Oil Co., 402 Second Natl. Bank Bldg., Saginaw, Mich. .. '26
Thompson, A Beeby, 18 St. Swithins Lane, London, E. C. 4, England .... '19
Thompson, B. E., Box 737, Fort Worth, Tex. .... '24
Thompson, Charles L., Box 997, Eastland, Tex. .... '28
||Thompson, Edwin I., 1810 N. Jordan, Oklahoma City, Okla. .... '31
Thompson, Evan G., Box 800, Tyler, Tex. .... '29
Thompson, James D., Jr., Room 3, Amarillo Natl. Bank Bldg., Amarillo, Tex. .... '23
Thompson, R. R., 1609 Frederick St., Fort Worth, Tex. .... '20
Thompson, Sheridan A., Magnolia Petr. Co., Box 1406, Shreveport, La. .... '23
Thompson, T. C., Box 84, Vernon, Tex. .... '22
Thompson, Wallace C., Box 807, Tyler, Tex. .... '20
||Thompson, William Allen, Route 1, Des Moines, Iowa .... '31
Thoms, Harold Wayne, Mill City, Nevada .... '30
Thomson, H. Britton, Pure Oil Co., Box 1007, Fort Worth, Tex. .... '23
Thornburg, D. H., Newhall, Calif. .... '23
Thornburgh, H. R., c/o Paul Weaver, Drawer C, Houston, Tex. .... '25
Thorne, B. L., Dept. of Natural Resources, Canadian Pacific Rwy., Calgary, Alta., Canada .... '30
Tickell, Frederick G., 652 Forest Ave., Palo Alto, Calif. .... '23
Tiedemann, Alex W., 48 Hofwiesen St., Zurich, Switzerland .... '26
Tieje, Arthur J., Cordova Hotel, Eighth & Figueroa, Los Angeles, Calif. .... '25
||Tierney, James A., Jr., Drawer T, Weston, W. Va. .... '30
Tillotson, Allen W., Box 1882, Tulsa, Okla. .... '28
Tims, Vergil E., Box 1555, Oklahoma City, Okla. (Mail returned) .... '27
Toler, Henry N., Box 546, Jackson, Miss. .... '26
Tollefson, E. H., 2 Sherman St., Wellsboro, Pa. .... '26
Tolmachoff, I. P., Carnegie Museum, Pittsburgh, Pa. .... '27
Tolwinski, Konstanty, Stacja Geologiczna, Boryslaw, Poland .... '31
Tomlinson, Charles W., 509 Simpson Bldg., Ardmore, Okla. .... '21
||Tompkins, J. D., Box 988, Wichita Falls, Tex. (Mail returned) .... '29
Tong, James A., Apartado 330, Maracaibo, Venezuela, S. A. .... '25
Torrey, Paul D., Torrey, Fralich & Simmons, Box 191, Bradford, Pa. .... '25
Touwaide, M. E., 48 Rue Vandermeersch, Brussels, Belgium .... '29
Townsend, Rex M. F., Room 2907, 120 Broadway, New York, N. Y. .... '27
Trager, Earl A., National Park Service, Room 4131, Interior Bldg., Washington, D. C. .... '18
Trask, Parker D., U. S. Geological Survey, Washington, D. C. .... '26
||Travis, Abe, 110 Mid-Co Bldg., Tulsa, Okla. .... '30
Trenchard, John, Route 2, Box 366-D, San Antonio, Tex. .... '30
Triplett, Richard L., Western Gulf Oil Co., 417 S. Hill St., Los Angeles, Calif. .. '28
Trout, L. E., 614 Cotton Exchange Bldg., Oklahoma City, Okla. (Mail returned). '19

Trowbridge, Arthur C., 1182 E. Court St., Iowa City, Iowa....................'22
Troxell, John N., Drawer F, Houston, Tex....................'25
Truex, Arthur F., 1815 Easton Place, Tulsa, Okla....................'19
Trumbull, Loyal W., 1835 Gaylord St., Denver, Colo....................'22
Trumpy, D., Sarawak Oilfields, Ltd., Miri, Sarawak....................'25
Tschopp, H. I., Bataafsche Petr. Mij., 30 Carel van Bylandtlaan, The Hague, Holland....................'27
Tuchel, Georg., Podbielki Str. 31, Hannover, Germany....................'27
||Tucker, Merwin B., Shell Petr. Corp., Box 117, Marshall, Okla....................'26
Tucker, Rietz C., Box 265, Morgantown, W. Va....................'21
Turman, Arthur F., 1111 Standard Oil Bldg., San Francisco, Calif....................'23
Turner, Joseph H., North Branch Development Co., Wellsboro, Pa....................'28
||Tweedy, Joseph L., Western Royalty Co., San Angelo Bank Bldg., San Angelo, Tex....................'20
Twenhofel, W. H., Univ. of Wisconsin, Science Hall, Madison, Wis....................'20
Tygrett, H. V., 2618 Newman St., Houston, Tex....................'23
Tyson, Alfred K., 840 Milam Bldg., San Antonio, Tex....................'24

||Ullstrom, Elmer T., Indian Territory Illum. Oil Co., Bartlesville, Okla....................'31
Umpleby, Joseph B., City Natl. Bank Bldg., Norman, Okla....................'19
||Upp, Jerry E., Conservation & Survey Div., Univ. of Nebraska, 108 Nebraska Hall, Lincoln, Neb....................'29
Upson, M. E., Box 737, Fort Worth, Tex....................'29
Uren, Lester C., Univ. of California, Geological Dept., Berkeley, Calif....................'26
Uwatoko, Kunio, Dept. of Geology and Mineralogy, Hokkaido Imperial University, Sapporo, Japan....................'29
Uyemura, Kimio, No. 4, Honcho-dori Gochome, Nakano-machi, near Tokyo, Japan....................'32

||Valentine, William W., 585 Winthrop Road, San Marino, Calif....................'30
Valerius, Claude N., Jay, Okla....................'25
Valerius, M. M., Jay, Okla....................'18
||Vallat, Eugene H., 505 Georgina Ave., Santa Monica, Calif....................'31
Van Burgh, Lisle R., 1491 Millar Drive, Glendale, Calif....................'21
Vance, Harold, Box 1505, Kilgore, Tex....................'31
Vance, Warner R., 508 N. Fifth St., Ponca City, Okla....................'27
Van Couvering, Martin, 704 Wright & Callender Bldg., Los Angeles, Calif....................'24
Van Dall, John E., 2837 N. W. Nineteenth St., Oklahoma City, Okla....................'22
van der Gracht, W. A. J. M., Staatstoezicht op de Mynen, Maastricht, Holland..'17
Vander Leck, Laurence, Box 117, Altadena, Calif....................'26
van der Linden, B. H., Wagenaarweg 12, The Hague, Holland....................'19
Vanderpool, Harold C., 304 S. Peters Ave., Norman, Okla....................'26
||Van der Veer, Howard J., 1611 Riggs Place N. W., Washington, D. C....................'30
Vandiver, Vincent W., Box 284, (Caripito), Port of Spain, Trinidad, B. W. I....................'20
Van Gilder, H. R., Box 83, Coudersport, Pa....................'24
†van Gogh, F. A. A., Zeekant 108. Schev., The Hague, Holland....................'21
Van Orstrand, C. E., 1607 Thirty-First St. N. W., Washington, D. C....................'31
Van Tuyl, Francis M., Colorado School of Mines, Golden, Colo....................'22
Van Zant, James H., Box 958, Enid, Okla....................'24
||Varley, Wayne, Collinsville, Tex....................'32
Vaudoit, Paul L., Shell Petr. Corp., Box 2099, Houston, Tex....................'26
Vaughan, F. E., 109 E. Foothill Blvd., Altadena, Calif....................'23
Vaughan, T. Wayland, Scripps Inst. of Oceanography, La Jolla, Calif....................'26
Veatch, A. C., 170 Broadway, New York, N. Y....................'20
Vedder, Dwight G., 408 Quinby Bldg., Los Angeles, Calif....................'29
Vernon, I. J., Coweta, Okla....................'25
Vernon, Jess, Box 896, Shawnee, Okla....................'25
Vernon, Robert D., Highclere, Plains Road, Mapperley, Nottingham, England....'26
Versluys, Jan, Nieuwe Achtergracht 125, Amsterdam, Holland....................'28
Vertrees, Charles D., Continental Oil Co., Box 1426, Midland, Tex....................'24
Ver Wiebe, Walter A., Univ. of Wichita, Geological Dept., Wichita, Kan....................'19
Vetter, John M., Rio Bravo Oil Co., Houston, Tex....................'24
Vickery, Ward R., 261 S. Delrose St., Wichita, Kan....................'28

Vincent, Herbert C. G., University Chemical Laboratories, Cambridge, England..'28
Voitesti, Ion Popescu, Str. Elisabeta 12, Cluj, Roumania....'26
von Buelow, E. U., 509 Seventeenth St., Denver, Colo....'28
||von Estorff, Fritz E., Hohenstr. 4, Potsdam, Germany....'30
||von Zwerger, Rudolf, Teltowerstrasse 17, Berlin-Zehlendorf, Germany....'30
Vorbe, Georges, Box 866, Midland, Tex....'26

Wadell, Hakon A., 5107 University Ave., Hyde Park Sta., Chicago, Ill....'27
Wagener, Charles H., 408 Park Ave., Park Hill Estates, San Antonio, Tex....'20
Waggoner, Arlington, Amity, Ark. (Mail returned)....'31
||Waggoner, Stephen Gose, 2013 Brown St., Wichita Falls, Tex....'29
Wagner, Carroll M., 1003 Higgins Bldg., Los Angeles, Calif....'20
||Wagner, Clyde L., 2559 S. Troost, Tulsa, Okla....'27
||Wagner, J. Basil, Box 37, Chandler, Okla....'27
||Wagoner, George E., Humble Oil & Refg. Co., Geophysics Dept., Houston, Tex...'28
Wahlstrom, Edwin A., Stanolind Oil & Gas Co., Hobbs, N. Mexico....'27
Wails, Elmer D., 518 Exchange Natl. Bank Bldg., Tulsa, Okla....'31
Waite, V. V., 5116 Victor St., Dallas, Tex....'17
Waldschmidt, W. A., Colorado School of Mines, Golden, Colo....'26
Walker, K. A., 325 W. Sixth St., Bristow, Okla....'30
Walker, Lucian H., 326 Beacon Life Bldg., Tulsa, Okla....'20
Walker, W. L., 1166 Subway Terminal Bldg., Los Angeles, Calif....'18
Wall, Earle R., 210 N. Tenth St., McAllen, Tex....'29
||Wall, Thomas E., Box 188, Sulphur, Okla....'30
Wallace, Davis M., 112 W. Houston St., Tyler, Tex....'27
||Wallace, Glenn E., 123 N. Ninth St., Duncan, Okla....'30
||Wallis, William E., Cia. de Petroleo Mercedes, S. A., Apartado 269, Monterrey, N. L., Mexico....'30
||Walter, Karl L., 607 S. Ogden, Denver, Colo....'29
||Walters, Mason G., 110 Main St., Port Allegany, Pa....'28
Walters, Ray P., Romano Americana, 126 Calea Victoriei, Bucharest, Roumania...'20
Waltman, W. D., 601 Edison Bldg., Fifth at Grand, Los Angeles, Calif....'29
||Walton, O. E., Box 817, San Angelo, Tex....'30
Wanenmacher, Joseph M., Geological Dept., Science Hall, Madison, Wis....'27
Wanless, Harold R., 126 Natural History Bldg., Urbana, Ill....'32
Wantland, Dart, 600 Fourteenth St., Golden, Colo....'31
Ward, Freeman, Lafayette College, Easton, Pa....'30
Waring, Gerald A., 1630 Park Road, Apt. 301, Washington, D. C....'23
Waring, W. W., Tropical Oil Co., Geological Dept., Barranca-Bermeja, Colombia, S. A....'29
Warner, Charles A., Box 1779, Houston, Tex....'19
Warner, J. Laird, Route 1, Box 99, McAllen, Tex....'30
Warner, Julius H., Wilda Bldg., Denver, Colo....'21
||Warner, Ralph E., Y. M. C. A., Bradford, Pa....'31
||Warren, Howard C., Box 1131, Houston, Tex....'28
Warren, Van Court, 812 Subway Terminal Bldg., Los Angeles, Calif....'23
||Warthin, Aldred S., Jr., Vassar College, Geological Dept., Poughkeepsie, N. Y...'28
Washburne, Chester W., 149 Broadway, New York, N. Y....'18
Wasson, Harold J., 25 Broadway, New York, N. Y....'27
Wasson, Isabel B., 606 Thatcher, River Forest, Ill....'27
Wasson, Theron, Room 2308, 35 E. Wacker Drive, Chicago, Ill....'20
Waterfall, Louis N., Union Oil Co. of Calif., 1114 Union Oil Bldg., Los Angeles, Calif....'24
Waters, James A., Box 2880, Dallas, Tex....'25
Watkins, William A., Standard Oil Co., S. A. Arg. Plaza Huincul F. C. Sud., Argentina, S. A....'23
Watson, C. P., Milham Expl. Corp., 1709 W. Eighth St., Los Angeles, Calif....'25
Watson, Joseph D., Turman Oil Co., 518 Exchange Bank Bldg., Tulsa, Okla....'21
||Watson, W. Verde, Midwest Refg. Co., Roswell, N. Mexico (Mail returned)....'27
Weatherby, B. B., 1123 E. Twenty-Fifth St., Tulsa, Okla....'30
Weatherston, Douglas, 408 W. Brazos St., Victoria, Tex....'30
Weaver, George A., Box 377, Palestine, Tex....'26
Weaver, Paul, Drawer 2100, Houston, Tex....'20

||Webb, James A., 902 San Pedro, San Antonio, Tex. .... '30
Webb, John B., 29 Wilberton Road, Toronto, Ont., Canada .... '29
||Weddle, Herman W., Box 1390, Station C, Los Angeles, Calif. .... '29
||Wedel, Arthur A., Box 327, Mt. Pleasant, Tex. .... '32
||Weed, W. F., Box 660, Beaumont, Tex. .... '26
Weeks, Albert W., 1118 City Natl. Bank Bldg., San Antonio, Tex. .... '27
Weeks, Herbert J., Sun Oil Co., 1608 Walnut St., Philadelphia, Pa. .... '24
Weeks, Lewis G., c/o National City Bank, Sao Paulo, Brazil, S. A. .... '24
||Weeks, Warren B., 649 E. Park Place, Oklahoma City, Okla. .... '29
Wegemann, Carroll H., Crown Central Petr. Corp., Box 1759, Houston, Tex. .... '20
||Weidmann, Carl, Am Zweihonnschaftenwald 9, Essen-Bredeney, Germany .... '31
||Weintz, Clement A., Gearhart, Colorado, via Orchard .... '27
Weinzierl, John F., 607-8 Petroleum Bldg., Houston, Tex. .... '22
Weirich, T. E., 1714 S. Evanston, Tulsa, Okla. .... '21
Weisbord, Norman E., Apartado 10, Matanzas, Cuba .... '25
||Welch, Virgil H., 1809 N. Park, Shawnee, Okla. .... '27
||Weller, J. Marvin, State Geological Survey, Urbana, Ill. .... '29
Wellings, F. E., Iraq Petr. Corp., Kirkuk, Iraq .... '24
Wells, Lloyd E., 806 Eighth St., Wichita Falls, Tex. .... '23
Wells, Samuel W., Box 1266, Okmulgee, Okla. .... '19
Welsh, LeRoy G., 1920 Berkeley Place, Fort Worth, Tex. .... '19
Wender, W. G., Box 1058, Cisco, Tex. .... '26
Wendlandt, E. A., Humble Oil & Refg. Co., Box 598, Tyler, Tex. .... '24
Westby, Gerald H., Empire Oil & Refg. Co., Geological Dept., Bartlesville, Okla. .. '23
||Westcot, Frank S., Box 464, Baytown, Tex. .... '31
||Westheimer, Jerome M., 401 I St., S. W., Ardmore, Okla. .... '32
||Wethington, William O., Nash, Okla. .... '30
Weymouth, A. Allen, Box 750, Coalinga, Calif. .... '29
||Wharton, H. Jerome, Apartado 234, Maracaibo, Venezuela, S. A. .... '28
Whealton, Rowland G., 694 Subway Terminal Bldg., Los Angeles, Calif. .... '25
||Wheeler, Carlton W., Box 1555, Oklahoma City, Okla. (Mail returned) .... '20
||Wheeler, Girard E., 780 St. Marks Ave., Brooklyn, N. Y. .... '29
Wheeler, H. A., Security Bldg., St. Louis, Mo. .... '27
Wheeler, James D., Box 595, Henderson, Tex. .... '29
Wheeler, Orby Clinton, International Petr. Co., 56 Church St., Toronto, 2, Ont., Canada .... '26
Whisenant, J. Barney, Box 143, Laredo, Tex. .... '25
||Whitaker, Harvey, 723 W. Cypress St., San Antonio, Tex. (Mail returned) .... '31
Whitcomb, Bruce, Groesbeck, Tex. .... '24
*White, David, U. S. Geological Survey, Washington, D. C. .... '19
White, Edwin E., Box 591, Huntington, W. Va. .... '19
||White, Gordon H., Shell Oil Co., Higgins Bldg., Los Angeles, Calif. .... '29
White, Kessack D., Caixa Postal 3532, Sao Paulo, Brazil, S. A. .... '22
White, Luther H., 211 E. Jasper St., Tulsa, Okla. .... '20
White, Maynard P., Gypsy Oil Co., Box 30, Ardmore, Okla. .... '25
White, Roger F., Bank of America Bldg., Los Angeles, Calif. .... '23
White, Stanley B., Box 981, Tulsa, Okla. .... '24
Whitehead, R. Brooks, 702 Magnolia Bldg., Dallas, Tex. .... '19
Whitehead, W. L., 222 Charles River Road, Cambridge, Mass. .... '29
Whiteside, Robert M., Box 1191, Tulsa, Okla. .... '28
Whitney, F. L., University Station, Austin, Tex. .... '20
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* The name, Southwestern Association of Petroleum Geologists, adopted at Tulsa, Oklahoma, February 9–10, 1917, was changed to The American Association of Petroleum Geologists at Oklahoma City, February 15–16, 1918.

† Died, November 25, 1927.

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Memorial

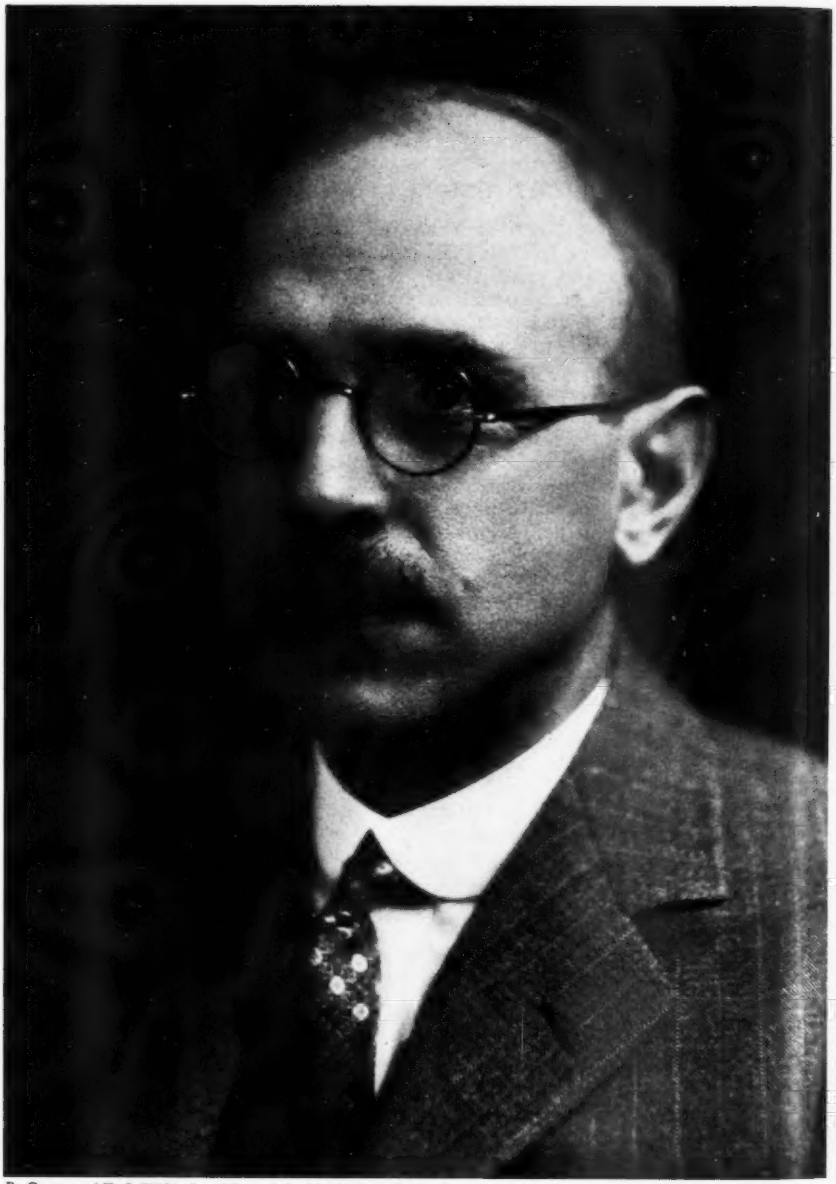
EULOGY TO SIDNEY POWERS[1]

We are gathered together to-day in an attempt to do homage to the memory of one of our fellows, suddenly stricken in the prime of life. In the face of the catastrophe words become but a poor and halting vehicle to express our inner feelings. Nature, in its inscrutable fashion, has again taken its toll, and we grope in helpless human incompetency to do merited honor to the departed. What can we do—what can we say—on this occasion that would meet with his approval? Those who knew him best are for the first time startlingly aware that he was prone to suppress details of his private life and his own participation in scientific problems even to the point of complete self-effacement. They feel that he would wish to let his accomplishments stand for themselves, divested of all sentimentality, even of all the commendation and praise which his fellow workers would so willingly accord. Judging by his customary outward expression, one might conclude that he would be unwilling to have mentioned any of those personal qualities and attributes which must be expressed if a full measure of justice is to be done his memory. Yet he was always so ready to commend the meritorious work of others, we must conclude that he would not be unwilling to have others say about him the things he was, with most commendable modesty, unwilling to say for himself.

Sidney Powers was without question one of the leading geologists of his generation. He combined the rare quality of proficiency both in the theoretic and applied phases of the science, and in recent years he has been classed by many as the most proficient geologist in the oil industry. With tireless energy he pursued the study of the science of oil geology, including its latest development, geophysics, and was always a leader in the most advanced thought of the time. His education in the field of geology, first aroused by stimulating contact with a favorite professor during his senior year at Williams College, continued unabated throughout the period of his specialized training at Harvard University and the entire span of his subsequent life. While yet a student at Harvard it was said of him by the faculty that he was even then more conversant with the literature of geology than anyone else in the University. Believing firmly that the best training for a geologist was in the field, he traveled extensively both at home and abroad, and acquired an enviable reputation which spread, through the influence of his writings and personal contacts, well beyond the confines of his native country. The esteem in which he was held was amply evidenced by the numerous honors bestowed upon him by various scientific organizations.

His outstanding success in the field of science was the rare ability to originate ideas. He was consistently ahead of his associates in correctly visualizing and forecasting the next step ahead. In this age of rapidly expanding scientific discovery, when most men tend to become muddled and confused by

[1] Delivered at funeral service at All Souls Unitarian Church, Tulsa, Oklahoma, November 7, 1932.



By Courtesy of H. J. Whitlock and Sons, Ltd., Birmingham, England

SIDNEY POWERS

the kaleidoscopic changing panorama, the several steps were correctly synchronized in his lucid reasoning, were winnowed, and the applicable portions promptly utilized to practical ends. With the details of practical application he was less tolerant, being usually content to delegate to others the working out of the routine procedure. His mind and energy were thus kept clear for major problems.

His achievements both as a scientist and an economic geologist need not be further stressed before a group composed in such large part of friends and co-workers. They are too well known to justify additional comment. His writings alone will stand as enduring contributions to science, and would, in number and quality, do credit to a career of double the span of his all-too-short life.

Next, what shall we say of him as a man? His modesty and self-effacement undoubtedly led him to undervalue his own work—certainly a rare trait of character in the current keen struggle for preferment. If a kindly appreciation of his efforts was not volunteered by others, his was not the disposition to argue the point. His disappointment, if such existed, was stoically concealed.

This stoic attitude manifested itself in various phases of his every-day contacts. Securely masked behind a seeming attitude of indifference or even gruffness, was a most kindly, sympathetic, and sensitive soul. Again a spirit of banter accompanied by flashes of incisive humor, successfully covered up and obscured inner feelings completely at variance with his seeming mood. When least evidenced by outward manifestation, his thoughts ran, far more than was generally recognized, to helping others. Many are the scientific papers of unskilled neophytes which have been carefully and painstakingly edited by his skilled hand, to appear in print without the slightest evidence of his handiwork. Many are the unexpected tokens of friendship, in the form of personal remembrances, brought back to family, friends, associates, employees, on the return from frequent trips to distant places. None have been more untiring in their efforts to relieve distress and suffering during these troublous times and to find employment for less fortunately situated co-workers,—and all done without the slightest urging from external sources.

Again this stoicism is suspected both by family and friends in the concealment of suffering and pain during the last years of ill health. Even after submitting to the surgeon's ministrations, followed by undoubted debility and pain, he carried on with a fortitude and seeming endurance which was a continual source of surprise and admiration to all who were aware of the circumstances. Geology was the mainspring of his interest in life aside from family ties, and by it he was incessantly and relentlessly goaded to activity. He worked as actively, and led others to follow his example, in unremunerative pursuits such as the functioning of scientific organizations, as in the work upon which his livelihood depended. And all this extraneous labor he contributed unselfishly during spare time, without in the slightest degree neglecting his daily duties. Seldom has there been a more unselfish devotion to a cause in any field of human endeavor.

His moral rectitude and probity, his freedom from petty jealousy so common in any profession, his absolute insistence that due credit should be given for any individual contribution to science, however small, were recognized by all who knew him. He was ever more willing to take up the cudgel in behalf of another, in cases where he felt that complete justice had not been done, than

to defend himself under similar circumstances. Nothing short of the highest ethical standards of professional or personal conduct found any justification in his outlook on life.

His friends often wished for him that he might relax, that he might devote more time to customary diversions. But apparently, with full knowledge, he chose to compress into a brief lifetime the full measure of accomplishment, which so many are complacently content to expend in more leisurely fashion. A brilliant and dazzling career was the net result of this unremitting toil. His life was literally burned out in the ardor of the burning, and we, the survivors, are the losers by its untimely ending.

More we might willingly say with ample justification. But why linger when the high lights of his career are so widely known? Biographical details can scarcely add to a brief expression of appreciation. We mourn the loss of a friend, an ornament and an honor to the profession, and with sadness we reluctantly recognize that his life story is complete, that henceforth he must remain to us only an inspiring memory.

W. E. Wrather

BIOGRAPHY OF SIDNEY POWERS

Since success in life depends largely on mental and physical inheritance and on environment, it seems advisable, if we are to understand the intellectual qualities, the accomplishments, and the successes of Sidney Powers, that we review briefly his ancestry and analyze the surroundings in which he lived.

The root of the Powers family has been traced back to Walter Power, who was born in England and came to America when a small boy. Moving up to the first son of the sixth generation, or to Sidney's grandfather, we find that William Powers, of New Hampshire, married Deborah Ball, also of New Hampshire, on February 22, 1816. This couple was the founder of the Lansingburgh family who have lived at Troy for more than a century, within a hundred yards of the site of the original home. In energy, ability, initiative, and public-spiritedness, Sidney was like his great-grandmother (Deborah Ball). Those who knew the great-grandson well, will understand this sentence from a letter which was written about the great-grandmother: "Perhaps no human being . . . ever hated more heartily ostentation, insincerity, and words without meaning."

While the preceding inherent attributes were so pronounced in Sidney, some obvious resemblances to his parents were his mother's keen thoughtful eyes, his father's voice, and his interminable propensity for work.

Sidney's maternal grandfather, Edward N. Page, came from Middlesex, England, about 1850. He married Betsy Edge, also from England, at Boston Massachusetts, June 21, 1852. After 1863 Mr. Page engaged in the manufacture of iron pipe in Cohoes, New York, the family living in a beautiful historic house in Waterford near by.

Sidney's mother (Matilda Wheeler Page) was educated at Saratoga Springs in Temple Grove Seminary, now the Scidmore College of Fine Arts. His father (A. W. Powers) was born on January 15, 1862, at Troy, New York, in the "Powers Homestead," an old brick house just south of the home where he and Mrs. Powers now live. A. W. Powers was graduated from Greylock

Institute in South Williamstown, Massachusetts, and following graduation he traveled a year in Europe and attended the college of France, in Paris. After returning to Troy he entered the already well established family business of D. Powers and Sons. He married Matilda Wheeler Page, June 25, 1884, and Sidney, the only child, was born September 10, 1890.

Sidney was born into an atmosphere created by successful and highly respected business men and women; it was in this environment that he spent his early life, and yet when it came time for him to choose his own life's work, it lay in an entirely different field.

As a boy he was especially interested in books of travel, but found little pleasure in the popular romantic novel. Rudyard Kipling's stories delighted him, possibly because their plots were laid in strange lands. A good amateur stamp collection, which he gradually acquired while in grammar school and academy, may have been the outgrowth of this same desire to learn about foreign countries.

Born of kindly, sensible, well-to-do parents, Sidney led a wholesome life and had material and cultural advantages that most young men lack. The paternal "allowance" was not a handicap to scholarship, but an aid, because it permitted him to spend all of his time in gaining knowledge and if he desired to carry on research, the family budget was sufficient. This was all conducive to the development of originality and resourcefulness.

He became interested in forestry and spent the summer of 1910 at the Yale Forestry School. Later he imported 10,000 white pine seedlings from France, for planting on his father's farm near Brandon, Vermont, and raised many thousands of trees from seed. His father encouraged his interest in reforestation of the farm, mainly because it gave Sidney an additional outlet for his energy, his father's theory being that if boys are kept busy, bad habits may be averted.

He prepared for college at the Troy Academy, Troy, New York, and entered Williams College in the fall of 1907.

During his Freshman and Sophomore years, he was not distinguished for his scholarship, notwithstanding his industry. This was doubtless due both to immaturity and to the character of the prescribed subjects. He seems to have found French and German more a test of memory than of intelligence. It is evident that he chose his courses carefully because of their value as mental tools. He elected courses in mathematics during every semester of his college course, and in one semester took two such courses. It is rather surprising to find that he had no courses in history, philosophy, fine arts, or English, except required Freshman English. When he reached his Junior year, and was able to elect courses in the natural sciences, he quickly became known for his mental alertness, keen observation, ability, and industry.

Why did he decide on geology as a life work? A special paper on "The Peat Bogs of the Northern Berkshires" may have led to the decision to take graduate work in geology. He entered into his task with enthusiasm. He read all the available literature on the subject and then spent his spring vacation making borings of bogs in New York, Massachusetts, and Vermont, in order to get samples from different depths and to determine the thicknesses of the deposits. The resultant paper was so excellent and was so well illustrated by drawings and photographs that he used those parts dealing with floating islands as an article for *The Popular Science Monthly* (now the *Scientific*

Monthly). The article was accepted and extracts from it appeared in the *Literary Digest*.

Sidney attended the graduate schools of Massachusetts Institute of Technology, 1911–13, and of Harvard University, 1913–15, and from the beginning impressed his fellow students and the faculties by his remarkable capacity to read and digest the geologic literature. He was by far the best posted student on recent geologic publications in the department of geology and his extremely logical mind automatically classified and recorded what he read to the extent that he was able to refer to it whenever the occasion demanded, or to look up the original article without delay. Perhaps one task, outside of his regular work at Harvard, that helped to familiarize him with the literature, was the cataloging of the exhaustive library of Professor J. B. Woodworth. His early intense interest in perusing geologic literature perhaps stimulated his desire for his own library, for while he was still at Harvard he made a substantial beginning on his comprehensive and valuable personal collection of geologic literature that now covers all phases of geology and all parts of the world.

As a student he showed remarkable independence of mind and also a great deal of originality and thoroughness in dealing with any assignment. His capacity and desire to delve into the fundamental principles of any problem was recognized by faculty members, who turned to him for a detailed study of special topics. They knew the subject would be traced to its source and the presentation would be clear and effective. It would also be original, for Sidney seldom accepted the word of even the highest authority without a struggle. He delighted to fight alone on the less popular side and he was not disturbed by his isolation.

Students like Sidney, with the capacity for thoroughness, willingness to work, and eagerness to learn, make teaching worth while. He received his M.S. degree from the Massachusetts Institute of Technology in 1913, and his A.M. and Ph.D. degrees from Harvard in 1915.

As evidence of the high esteem in which he was held by the Harvard faculty, he was awarded the coveted Sheldon Fellowship for two years. The first year (1914) was spent at Harvard, and the second year (1915) he traveled to Hawaii and Japan, where his tireless energy and desire for information carried him into the remote corners of these islands. The income of the Frederick Sheldon Fund is used for the "further education of students of promise and standing in the University, by providing them with facilities for foreign education by travel after graduation or by establishing traveling scholarships." Returning from Hawaii he spent the next year (1915–16) as research fellow at Harvard.

He was a persistent collector of geologic specimens. On the Harvard Summer School trip in 1912, in the Three Forks area, Montana, he collected and neatly labeled rocks which were shipped to his home. A generous collection of these, and many others, was donated to Wesleyan University, where numerous students know more of the geology of Canadian mining regions, of Nova Scotia, of Hawaii, and of Japan because of this gift. Only recently Williams College received some excellent specimens for its collection. This habit continued through the years, for he collected valuable specimens on each field trip. There was hardly room in his office, at times, for the things he brought back, ranging from large boulders to dried sea horses.

An exceptionally altruistic spirit was one of Sidney's outstanding charac-

teristics. During all of his active professional life he was thinking of others. His loyalty to friends and associates was extraordinary. He was seldom too tired or too ill or too occupied to visit an intimate friend or a near relative of an employee, at considerable personal inconvenience, even though the call was but a few minutes long. Because of his unselfish interest in others, his contacts were many. It is doubtful whether there is another geologist whose personality and interests have touched as many members of the profession. He not only knew much about them personally and the work they were doing, or were capable of doing, but he could tell you their past and present commercial or University connections.

In almost any small group of Mid-Continent geologists that may gather together, there is likely to be one or more who can tell of assistance in some way received from him. Whenever, in his association with fellow geologists, he learned that some one had a worth-while idea or contribution to the science, he urged that the material be published. His efforts, however, did not stop there, but continued with aggressiveness until the manuscript was ready for the printer. It is regrettable and unfortunate that mention and appreciation of his helpful criticisms fail to appear in the finished product, even in the form of a slight acknowledgment. He did not seek such recognition, for his interest was centered solely in the product. He bought innumerable postcards and used them to inform fellow workers of some reference that would throw light on their problems, of some pertinent observations in the field that had a bearing on problems of others, or for asking some co-worker to furnish information bearing on some problems of his own. In addition to his eagerness to help others interested in furthering the science, he had a very definite personal interest in all geologists. He was ever alert to bring an employer and an employee together. For the last few years it was to him a disturbing fact that so many geologists were out of employment, and he was actually instrumental in securing work for some of them.

Sidney's real personality was misunderstood by many geologists and others who failed to see his kind and most forgiving nature, securely hidden behind his frank and often blunt criticism and outspoken intolerance of laziness, inefficiency, and sham. As he approached middle life he became more tolerant and less impatient without losing his valuable stimulating qualities of mind. He was not critical of men, but may have been critical of ideas which they advanced. He was admired for his unusual capability in his professional and commercial capacity, but he was loved by his close friends for the inner man whom they knew to be considerate, generous, honest, and extremely fair. In spite of his seemingly tireless effort to complete his own work in record time, he possessed the generosity and willingness to help others.

His vigorous desire for truth and his unrelenting search for sound principles on which to base his conclusions and geologic interpretations were among his most valuable attributes. These tendencies which he developed early in life continued with him in his professional career.

He was an original thinker and no blind follower of precedents. He was inclined to overturn accepted things and had a wholesome and stimulating lack of reverence for things already done, until he personally had examined the soundness of the foundation. He had little pride of opinion and seemed ready to abandon any idea he had advanced, if it proved to be unsound; but, needless to say, convincing evidence had to be presented before he would

abandon his idea. He always brought ideas to any conference. They were frequently disturbing ideas because they departed from accepted opinions, and that made them valuable.

One of the outstanding and valuable aspects of his activity was his breadth of interest. In addition to his work in petroleum geology, by which he obtained his livelihood, he found time to consider geologic problems for the sake of pure science, and possessed the rare ability of coördinating and harmonizing pure and applied geology to the enhancement of both. He was admired and will be remembered for the unique combination of resourcefulness and originality in starting new projects and for his pertinacity and thoroughness in carrying them to a successful conclusion.

Sidney kept himself well informed as to the oil developments and prospects, from a geological standpoint, of every actual and potential area in the world. He always maintained most voluminous correspondence from everywhere in the world where oil geologists were working, and whether it was China or Japan or any of the Near East areas, or Africa or South America, he could at any time give a very comprehensive picture of what the oil possibilities or geology might be.

He had a remarkable ability for getting all the information available in the particular area that he had under consideration. His reports always contained a complete and detailed history of field developments in the area, because he would never leave an area until he had ferreted out everything that was known from both a practical and a technical viewpoint.

His breadth of interest is also indicated by the number and character of the scientific societies of which he was an active and interested member: American Association of Petroleum Geologists (1917); Geological Society of America (1920); Society of Economic Geologists (1921); Institute of Petroleum Technologists (1925); American Institute of Mining and Metallurgical Engineers (1917); and Tulsa Geological Society (1920).

Sidney at heart was a scientist and would have been content to work out his geology, remote from commercial affairs, except for the realization that he must earn a livelihood and that he felt he had a usefulness in applying science to commerce. In his characteristic way of looking ahead, he probably saw greater opportunities to further the science in petroleum geology because of the opportunity not only to study the surface rocks in detail, but the chance to study and decipher subsurface formations from logs and cuttings of wells drilled for oil and gas. Accordingly he accepted a position with The Texas Company as division geologist in the summer of 1916. His first assignment was in northeast Texas to study interior salt domes. Here living conditions were terrible but nothing seemed to bother Sidney. He kept at his work with indefatigable energy every day in the week from sun-up to sun-down. The physical hardships of that summer must have told on his constitution, yet he never uttered a word of complaint. He was transferred to southern Oklahoma in the fall of 1916 to study the oil and gas possibilities of that region. Here, from a study of material shot from a well in the Healdton field, he recognized that, on the top of that structure, the Pennsylvanian rocks rest directly on Ordovician rocks at a depth of 875 feet. In 1917 he published his conclusions and for the first time gave to the profession the conception of buried hills and emphasized the importance of unconformities in a search for new oil fields.

In 1914 he passed the civil service examination for the position of assistant geologist in the United States Geological Survey, but he could not consider Survey employment for the next three years because he was engaged in commercial work. In the fall of 1917 he was offered positions by both the Illinois and Federal Surveys, and accepted an appointment as assistant geologist with the United States Geological Survey on September 17 of that year.

His first assignment with the Survey was in September, 1917, as head of a field party engaged in structural mapping in the Osage Nation, Oklahoma. In December, 1917, he was transferred to study the structure of the Cretaceous and older rocks in the Madill-Dennison area in Texas and Oklahoma, and later he examined salt domes and reported anticlines in Smith and Van Zandt counties, Texas. He returned to the Osage Nation in February, 1918, to continue work on that project and in May, 1918, was assigned to duty at Lawton, Oklahoma, for the purpose of studying the oil and gas possibilities at the Fort Sill Military Reservation. While making this study, he was requested by the commanding officer to study the water supply for the military camp at Fort Sill and for the city of Lawton. The results of his Survey work appear in the official publications, and are listed in the bibliography attached hereto.

A few days after his appointment to the Survey, in September, 1917, he received a commission as Second Lieutenant in the Engineer Officers Reserve Corps, but did not enter active Army service until June 11, 1918, because the Survey interceded and asked that he engage temporarily in civil duty, since the Survey needed well trained and competent geologists in the field in search of new oil reserves for war emergency.

He resigned from the Survey and entered active military service June 11, 1918, reporting at Fort Sill, Oklahoma. He was in the military hospital from June 11 to August 1 because of an operation for mastoiditis. He attended the Engineer Officers' Training Schools, Camp Lee and Camp A. A. Humphreys, Virginia, until October 1, and was then transferred to the 6th Training Regiment and sailed for France, October 26, as a casual officer for special geological duty. He reached Liverpool November 8, 1918, and from there went to the general headquarters at Chaumont, France. He returned to Philadelphia February 21, 1919, and received his discharge from active military service February 23, 1919.

In the early spring of 1919 he became associated with E. L. DeGolyer who, a short time later, organized the Amerada Petroleum Corporation and chose Sidney as chief geologist, in which capacity he served from 1919 to 1926; after that date, until his death, he was designated consulting geologist. His work with the Amerada Petroleum Corporation speaks for itself, leaving no doubt that he delivered full value in the field of petroleum geology. In commenting on his work with the Amerada, mention should be made of the opportunities afforded to Sidney to go to any place within reason that he chose, for the purpose of gaining geologic knowledge. He was given a free hand and roving commission which permitted him to carry to a successful conclusion the study of various geologic problems which he considered would help him in his work as a petroleum geologist. In addition to this, he was permitted to publish any of the results of his investigations, withholding only that which his discretion dictated. His reports were always clear, and he

never hesitated in backing up his judgment by very definite recommendations. After a personal study and examination of any prospect, it made no difference to him how many other geologists differed with him, he would hold to his own views. He was always able to make up his mind, which was of the greatest importance and value to his associates.

The foregoing qualities were the result and outgrowth of those sterling attributes previously mentioned, namely, his skepticism of geologic work poorly done, his eagerness for geologic truth, and his inexorable search for fundamental principles on which to base sound conclusions.

The Crinerville oil field, in Carter County, Oklahoma, was discovered in June, 1920. It is located in an area of complicated geology that required careful and painstaking field work based on thoroughness and mature judgment. Sidney's recommendations regarding this prospect were severely criticized by most geologists who claimed familiarity with the region, but his judgment was unshaken by the criticism and was entirely vindicated.

The science of geophysics was introduced to the oil fraternity a few years ago and has been developed as an aid to the geologist in his search for new oil fields. Sidney was associated with the early work of geophysicists and played an important part in the development of seismographic work through and by his extremely critical attitude. Yet he was always open-minded. In characteristic fashion he examined the basic principles of the instruments and methods and finally completely satisfied himself that the results of work properly done by capable geophysicists, and interpreted by competent geologists, may be relied on to represent true geologic conditions.

Among Sidney's contributions to the science was the Oklahoma Geological Map, the preparation of which was begun early in June, 1923. The final colored map was issued in December, 1926, by the United States Geological Survey. It was printed in 22 colors with 105 separate colored patterns. It was proposed as a coöperative project between the United States Geological Survey, the Oklahoma Geological Survey, the Tulsa and other geological societies of the state, and some of the oil companies. The expected financial support from the State was not realized because Governor Walton vetoed the bill appropriating funds for the Oklahoma Geological Survey for the next two years. He also turned down Sidney's personal appeal for funds for the map project. It took more than a Governor's refusal of support to check Sidney's enthusiasm and he appealed to the geologists of Oklahoma for the necessary funds and also requested their coöperation in supplying information. They generously responded with contributions and pledged information.

The money collected amounted to $3,396.25 from a total of 260 subscribers. Solicitation of funds, by Sidney personally, was exclusively among geologists, but subscriptions were accepted from oil operators and companies when sent at the request of geologists employed by them. Sidney took a personal interest in the map project and he used every effort, not only to speed up prompt initiation of the project, but also to effect prompt publication.

He made suggestions regarding the form of compilation and sources of information. He personally secured many maps from different sources and requested geologists to make information available. He also arranged for office and field conferences and provided office space and facilities for a period of several months in Tulsa. Publication of the map, which gave for the first time the results of detailed mapping on more than half the state, was an

important addition to the knowledge of the geology of the United States and at the same time it stands as a monument to Sidney's ability, leadership, and interest in the geology of Oklahoma.

After Governor Walton vetoed the appropriations for the State Survey, Sidney secured from the Governor $2,500.00 for the publication of maps by C. W. Honess, of portions of McCurtain, Choctaw, Pushmataha, and LeFlore counties, for use in Bulletin 32 of the Oklahoma Geological Survey, and he assumed charge of letting a contract for the engraving and printing with Hoen and Company.

Also, a draft of an appropriation bill for the Oklahoma Geological Survey was written by Sidney in January, 1924. He and several other geologists called on Governor Trapp and a committee of the Legislature and presented a plea in behalf of the appropriation. This bill was finally passed by the Legislature and approved by the Governor.

The history of the development of The American Association of Petroleum Geologists is inseparably linked with the life and work of Sidney. Its success and the present high standards of the *Bulletin* are in large part due to his efforts. His name appears on the first roster which was published in 1917 as Vol. I, of the Southwestern Association of Petroleum Geologists, which was the fore-runner of The American Association of Petroleum Geologists. The activity of the Association that came nearest to Sidney's heart was probably the publication of important information pertaining to petroleum geology. He was a generous and consistent contributor to the *Bulletin* himself and in addition to his own articles, should be given credit in part for many of the other published papers.

He was widely acquainted and on his many travels was constantly seeking subjects of interest for publication in the *Bulletin* and authors who might be able and willing to write on these subjects. During much of his most active period, he was almost daily sending post-card suggestions to the editor concerning contributions for the *Bulletin*. He was particularly anxious for the younger men to publish papers and in many cases he supplied the necessary inspiration. If he thought any co-worker had problems suitable for publication, he gave them no peace until the paper was submitted to the editor. It is not known how many manuscripts were practically rewritten by him before they appeared in print.

One unique circumstance will suffice to illustrate his desire and determination to see what he considered to be valuable information published. There were certain geological features about an area that Sidney wanted in the literature and he picked the author and requested the paper. The paper was not forthcoming, so Sidney outlined the subject matter of what he wanted and sent it to his appointed author with the request that the details be filled in and returned. The author still either refused or neglected to finish the paper; finally Sidney wrote the paper and signed the author's name.

Another phase of the activities of the Association, in which Sidney was a zealous worker, was securing new qualified members. Through his efforts, many new names were added to the roster, especially geologists in foreign lands.

He was vitally concerned with the ethics of the Association and its members and was actively interested in the preparation and adoption of the code of ethics.

He was always intensely interested in the financial status of the Association, and particularly so in the last few years since the unemployment among geologists has prevented many members from maintaining their membership in good standing. His main concern was that the men were out of employment, rather than that they were unable to pay their dues. It was evident several years ago that the normal income was insufficient to publish valuable available material. To meet this need, a special fund called "Revolving Publication Fund" was established with surplus funds collected by the local committee for the fall meeting of the Association in New York, November, 1926. Sidney participated in the conception of this fund and was ever alert in finding ways and means of adding moneys to it.

One of Sidney's outstanding contributions to the work of the Association, and one of his most lasting monuments, is the symposium, *Structure of Typical American Oil Fields*. He, together with a few co-workers, conceived the idea that valuable information regarding developed oil fields should be published that it might serve as a key to the yet unknown areas. He undertook the laborious task of choosing material for these volumes; of finding competent authors; of soliciting the papers; and of editing the manuscripts. He was officially designated editor of this symposium in three volumes. Volumes I and II have been published and Volume III is to be published during the current year.

The executive committee passed the following resolution on June 1, 1932: "*Official editor of Volume III, Structure of Typical American Oil Fields*. That the title page of Volume III, of the symposium on the structure of Typical American Oil Fields shall carry the following designation: 'Prepared under the auspices of the Research Committee, Alex. W. McCoy, Chairman. Compiled and edited by Sidney Powers.'"

He personally solicited many of the papers and did a great amount of editorial work for Volume III, which is to be dedicated to his memory. W. E. Wrather, one of his intimate friends and colleagues, has been chosen to complete the editorial work for this important volume.

Sidney was also the instigator of the symposium on "Occurrence of Petroleum in Igneous and Metamorphic Rocks" in the Association *Bulletin*, Vol. 16, No. 8 (August, 1932). He not only solicited many of these papers, but also did much of the necessary editorial work. While not appearing officially in the volume on *Geology of Natural Gas*, to be published in the near future by the Association, he contributed liberally of his time in soliciting papers and in editorial work and in urging immediate compilation and publication.

In addition to his tireless efforts on these special volumes, he gave time and energy to the work of the *Bulletin* of the Association and in a large measure is responsible for the building and maintenance of its present high standards.

His effort to persuade The Geological Society of America to accord fuller recognition to the scientific work of The American Association of Petroleum Geologists was in part rewarded when he, and other Mid-Continent geologists, were instrumental in bringing that Society to Tulsa for its 1931 annual meeting which afforded an opportunity for older scientists properly to evaluate petroleum geologists and their work.

Sidney Powers was elected president of The American Association of Petroleum Geologists in March, 1930, for one year and served on the executive

committee as past-president the following year. While he was president, it was obvious that when he knew that a member disagreed with him, he tried to place that member on some committee in order that he might discuss the particular problem with him. His criticism was usually blunt but was always good and to the point. He relished discussion and tried to bring men of diverse views together.

Sidney was elected a Fellow of The Geological Society of America, December, 1920, and rarely missed an annual meeting since his post-graduate student days. He frequently took an active part in the discussions of papers, which indicated the breadth of his knowledge and his ability to discuss problems of pure science. He was elected a member of the Council of The Geological Society of American in December, 1930, for a period of three years, and from then on he necessarily took a more active interest in the activities of the Society.

In his work with The Geological Society of America, as in all of his many other activities, he displayed tremendous energy and interest in doing all that could be done to further the cause of our science and to help along the different workers in it.

His interest and ability had become so recognized that he was made chairman of the committee which recently revised those by-laws of The Geological Society of America which were voted on during the holidays at the meetings in Cambridge (1932). This involved an immense amount of work and responsibility. He was given charge of this because of his own great capacity, very wide acquaintance with the field of geology and geologists, and the needs of the Society, and also undoubtedly because of the confidence reposed in him by the members of the Council who were in the best position to judge.

As a member of the Council and a Fellow of The Geological Society of America, he was keenly interested in the Penrose Bequest and in the manner in which the available funds should be spent, believing that the best interests of the Society would be served by fostering real research, and in the publication of pure scientific work already finished or in process of completion, for which there are no other available funds.

He was an ardent supporter of research in the field of geology, believing that through such medium the science of geology could be most effectively advanced. He was a member of the National Research Council, in which his colleagues admired his great energy in the stimulation of the research of Mid-Continent geology, and his efforts along this line greatly advanced the science to which he was devoted. Members of the Research Council, who worked with Sidney, valued his friendship and respected his judgment.

The International Geologic Congress is another organization devoted to science, in which he took some interest dating back to his student days at Harvard. He attended the twelfth session of the Congress at Ottawa, Canada, in 1913, where, it is said, he took part in scientific discussions that provoked considerable favorable comment regarding the breadth of this student's knowledge.

He was a delegate to the fourteenth session of the Congress at Madrid, Spain, as special representative of The American Association of Petroleum Geologists; the Society of Economic Geologists; the Tulsa Geological Society, and Williams College, Williamstown, Massachusetts.

Because of his general interest and activities in the field of geology and his wide experience, his services were sought on the organization committee and the petroleum committee of the sixteenth session of the International Geological Congress which will be held in Washington, D.C., July, 1933.

Sidney became a member of the Tulsa Geological Society in 1920. He contributed his full share to the programs, both in the presentation of papers and in pertinent discussions. His sharp witticisms added much to the success of the meetings, but more than this, he exerted an influence and inspiration that extended to all members. Many papers presented before this Society owed their inception to him, who, through his interest in, and knowledge of, men's work, was able to inspire the undertaking.

In vacations, in the popular sense, he seldom, if ever, indulged. His mental activity was remarkable. His mind seemed to need no rest, for he was so thoroughly interested and absorbed in his work that he seemed not to tire, at least mentally. Perhaps the diversity of angles from which he worked was in itself a rest. His idea of a vacation is illustrated by an incident in the early days of the Amerada. Its officials had spent considerable time in Mexico and naturally discussed the geology of that country, on which, at that time, Sidney had little or no first-hand information. At the first opportunity for a vacation, he spent two weeks in the oil fields of Mexico. His associates implored him to enjoy some real vacations, but the few he took were spent in places where he could increase his store of scientific knowledge.

Sidney chose to spend more time than the average professional man spends in pursuit of scientific information and in the preparation and publication of pertinent facts. In his busy professional life, so crowded with long working hours and fatiguing field trips by auto, train and airplane, he needed and found rest and relaxation in his quiet home. His own home life began in 1917, when he and Dorothy Edwards were married, September 10. She was a New England girl, with much the same kind of inheritance, environment and education as that possessed by Sidney. The family group, including the two girls, Deborah and Elinor, were a real joy and comfort to him and contributed much to his happiness and success.

We are astounded when we review Sidney's life, and we marvel at the amount of literary work and accomplishment that he was able to do in his few overcrowded years. His career as a contributor to science began in 1911 and continued practically without interruption until the last. His bibliography, which appears as a part of this memorial, contains 124 titles, including major contributions with reviews and discussions that cover practically the whole field of geology. His early writings include papers on vulcanology in Hawaii, Alaska, Japan, and the Pacific Islands, a small number of papers on paleontology, although he took no active part in this branch of the science, and a few deal with the geology of igneous rocks. He wrote a considerable number of papers dealing with dynamical and structural geology. In the field of general and areal geology, his papers cover areas in New England, Nova Scotia, Spanish Honduras and Guatemala, Rocky Mountains, Oklahoma, and Texas. He published a considerable number of papers on general geology in the Mid-Continent field and a considerable number more dealing with specific oil fields in Oklahoma, Texas, Kansas, Louisiana, Australia, France, Persia, Egypt, and Mexico. He also published papers dealing with geology of salt domes, petrology, and sedimentation. In addition to these papers, he pre-

pared many geologic notes on special topics and reviews and discussions of the work of other geologists.

The name of Sidney Powers is to-day, and probably always will be, primarily associated with the idea of "buried hills." It is characteristic of his vision and his pioneering instinct that, at a time in the history of petroleum geology when almost universal attention was focused on surface structure, he recognized and promulgated the importance of the study of material brought from the ground in the process of drilling. This early study of his probably marks the beginning of the now extensive use of drill cuttings to unravel the perplexing problems of buried or subsurface geology.

In 1922 he enlarged on the importance of buried hills and set forth the general principles of his ideas, pointing out the application in many oil fields of the United States. This was followed by a still wider study in which he showed the application of the principle of buried hills in various oil fields of the world.

His views were substantiated by the constant accumulation of material, and their value became so generally recognized that to-day the principle of buried hills and buried unconformities is recognized as second to none in petroleum geology.

A few of his other outstanding papers are "Interior Salt Domes of Texas," published in 1926; "The Seminole Uplift, Oklahoma," which appeared in 1927; and the "Age of Folding of the Oklahoma Mountains—The Ouachita, Wichita and Arbuckle Mountains of Oklahoma, and the Llano-Burnet and Marathon Uplifts of Texas," which was published in a bulletin of The Geological Society of America in 1928.

During the summer of 1932 he was working on the manuscript entitled "The Occurrence of Petroleum in the United States" with notes on Canada and Mexico, which was originally intended to appear as a chapter in a volume of *Das Erdöl*, a German publication. After this manuscript was practically completed, he found that there were no funds available for publication; nevertheless he decided to complete the manuscript, presenting the treatise in book form. The paper discusses the numerous fields and divisions of fields in the various major oil-producing areas in North America and a brief discussion of types of folding and oil accumulation and regional structural conditions, together with the age of formations and accumulation of oil.

Many facts regarding Sidney's deeds, traits of character, and achievements have been stated in this memorial that he, because of his enviable modesty, would never allow to be given, but the writer has attempted to outline briefly an extraordinary career in justice to the memory of our beloved and admired colleague. Even though his life was short, he accomplished more than most of us do in our full allotment of years. His passing away on November 5, 1932, creates a gap in American geology which none can fill. Geology has lost one of its real scientists. He may be compared with the old masters of geology who devoted their entire time and energy to science. Sidney Powers will be known by future generations for his able contributions to pure and applied geology, but, important as are his scientific achievements, his character was greater, because it typified service to others.

The writer has drawn freely on all possible sources of information that were known and available to him in the preparation of this memorial. Without the full coöperation of mutual friends and relatives, the facts about Sid-

ney's life and accomplishments would have been impossible to secure. Full acknowledgment and credit are thankfully given to all those who have contributed information.

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FRANK R. CLARK

TULSA, OKLAHOMA
February, 1933

ERASMUS HAWORTH

Doctor Erasmus Haworth, former state geologist of Kansas and for many years head of the department of geology at the University of Kansas, died at Wichita, Kansas, November 17, 1932. He was 77 years old. Thus was closed the career of an outstanding figure in the development of geology in the northern Mid-Continent region as applied to petroleum development.

In the first place, Doctor Haworth made notable contribution to knowledge of the stratigraphy and areal geology of Kansas, for the work done by him and his associates of the early Kansas Geological Survey furnishes the foundation on which later detailed investigations largely rest. Many of the familiar formation and group names in the Pennsylvanian and Permian

systems, such as Oread limestone, Cherokee shale, and such terms as Douglas and Shawnee, were introduced by him. They are widely used in neighboring states as well as in Kansas. These and other stratigraphic units defined by him have been studied by hundreds of petroleum geologists, and not only have been traced by them for long distances at the surface but have been identified far from the outcrop in well borings.

Next to be mentioned is Doctor Haworth's special interest in economic geology, including particularly the geology of petroleum and natural gas. Several of his important scientific papers were devoted to discussion of the oil and gas resources of Kansas. One of the most widely used reports of the Kansas Geological Survey was his Special Report on Oil and Gas, Volume IX, published in 1908. In his later years at the University of Kansas, Doctor Haworth devoted much time to private investigations of prospective oil- and gas-producing areas. He resigned his position as state geologist in 1915 in order to give larger attention to this private work, and in 1920 he relinquished also his teaching duties in order to devote all of his time to petroleum geology. He was connected directly or indirectly with exploratory work in many fields in the northern Mid-Continent, but especially in Kansas.

Finally, Doctor Haworth's work as a teacher of geology calls for special attention. From 1883 to 1892 he was a member of the faculty of Penn College in Oskaloosa, Iowa. At the end of this period opportunity came to return to the University of Kansas as professor of physical geology and mineralogy. Doctor Haworth thus took up the work as teacher and investigator of Kansas geology, for which he is chiefly known. For nearly forty years he met in classes the many students who enrolled for work under him. He was a capable teacher whose discourses in the class room were enlivened by graphic descriptions of innumerable personal observations. He had an inexhaustible fund of humor from which he liberally drew to illustrate a point or clinch an idea. He was familiarly known everywhere as "Daddy" Haworth, a title which amply indicates the general affection and esteem in which he was held by the student body.

Recognition of the practical importance of scientific training in the exploitation of the mineral resources of his state and other regions, led him to aid in establishment at the University of Kansas of a department of mining engineering. The growth of classes in geology and mining soon called for enlarged facilities, and in 1908 a separate building was erected to house the work in these fields. It is fitting that this building has come to be known as Haworth Hall.

Doctor Haworth was for many years a member of The American Association of Petroleum Geologists. He was an original fellow and life member of the Geological Society of America, and a life member of the Kansas Academy of Science. He belonged to the honorary fraternities Sigma Xi and Phi Beta Kappa and the social fraternity Beta Theta Pi. With his aid was established at the University of Kansas the first chapter of the geological fraternity, Sigma Gamma Epsilon, which is now so widely distributed in American universities.

Doctor Haworth is survived by his children, Henry Huntsman, also a geologist, Paul Eugene, Rose Elizabeth, and Margaret Josephine. Mrs. Haworth died at Wichita, Kansas, March 2, 1931.

Raymond C. Moore

Lawrence, Kansas

WILLIAM G. GALLAGHER, JR.

William G. Gallagher, Jr., fatally injured in an airplane accident at Wharton, Texas, on the evening of November 21, 1932, succumbed to his injuries early the following morning in the Baptist Memorial Hospital at Houston.

This tragic event seemed almost incredible to his close associates and many friends, who were forced to realize that such a young man of so forceful a character and vigorous physique had been taken from them.

Born in Brooklyn, October 13, 1898, he received his early schooling in Brooklyn and Mount Vernon, New York, attending high school in the latter place. His high school attendance was terminated with the entrance of the United States into the World War, by his voluntary enlistment in the navy, in which he served two years.

In the fall of 1919, he entered the University of California and distinguished himself in athletics, playing center on California's "wonder" teams of 1921 and 1922. He received the A.B. degree with geology as a major in 1923. He was a member of Sigma Chi, Theta Tau, and Golden Bear fraternities.

After graduation, he entered the employment of the Union Oil Company of California as an assistant geologist in the Rocky Mountain district, and was in the employ of its operating Texas subsidiary company, the Union Oil Company of Nevada, at the time of the fatal accident.

His residence while in the employ of this company shifted through the Rocky Mountain and Mid-Continent districts. He first resided at Casper, Wyoming. In 1925, while living at Shawnee, Oklahoma, he married Elfrieda Ankerson of Mount Vernon, New York. In 1927, he was appointed chief geologist for the Rocky Mountains and Texas for this company, with headquarters at Fort Collins, Colorado. When the Union Oil Company of California sold its Rocky Mountain holdings, he moved to Abilene, Texas, to take charge of the geological work in Texas for the Union Oil Company of Nevada. From Abilene, he moved to Beeville, Texas, his last residence.

The warmth of friendliness created by such a strong personality, which knew no ill will, endeared him to those with whom he came in contact.

His keen mentality, his intense application to the problem at hand, his high standard of living, and his honesty won him the respect and admiration of his associates and friends.

He is survived by his wife, now residing in Mount Vernon, New York, his mother and father, Mr. and Mrs. W. G. Gallagher, Sr., a brother, Jack, and his sister, Irene, all of Merrick, Long Island.

In the same fatal crash E. C. Templeton, geologist, who was working with Gallagher, was killed instantly, and the pilot, C. F. Lienesch, received serious injuries. The occupants of the plane were engaged in geologic work at the time of the accident.

S. GRINSFELDER

BEEVILLE, TEXAS
January, 1933

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 17, NO. 3 (MARCH, 1933), PP. 346-350

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

At the recent annual meeting of the Alberta Society of Petroleum Geologists, the following officers were elected for the 1933 term: president, A. J. Childerhose; vice-president, G. R. Elliott; secretary-treasurer, V. Taylor, 119 Sixth Avenue West, Calgary, Canada. A short technical session was held in which the following papers were contributed: "Public Relations," by S. E. SLIPPER; "Certain Types of Carbonaceous Sediments," by T. B. WILLIAMS; "Deep Drilling in Western Canada," by J. O. G. SANDERSON; "Faulting in the Coast Range of California," by B. F. HAKE.

At the weekly luncheon of the Fort Worth Geological Society, January 23, FRANK A. HERALD presented a paper entitled, "Some Ideas Relative to the Valuation of Petroleum Properties." This paper was published in the January 26 issue of *The Oil and Gas Journal* and the January 29 issue of *Fort Worth Star-Telegram.*

H. M. FRITTS, geologist for the Shell Petroleum Corporation at San Angelo, Texas, and Miss Frances Margaret Sullivan were married, December 31, 1932, at the home of the bride's parents in Big Spring. They will make their home in San Angelo, Texas.

The Society of Economic Geologists will hold its thirteenth annual meeting at Princeton, New Jersey, July 7–8, 1933. E. S. MOORE, University of Toronto, Canada, is chairman of the program committee.

The Sixteenth International Geological Congress meets at Washington, D.C., July 22–29, 1933, with field trips to several parts of the country. For further particulars write to W. C. MENDENHALL, United States Geological Survey, Washington, D.C.

A World Petroleum Congress, organized by The Institution of Petroleum Technologists, London, will be held in London, July 19–25, 1933. The Geology Section under the chairmanship of Arthur Wade, Aldine House, Bedford Street, London, W. C. 2, has planned three symposia for the technical program: on July 20, "Modern Developments in Geological Exploration"; July 21, "Geological Significance of the Regional Distribution of Oil Fields"; and July 24, "Geological Aspects of Oil-Field Development."

CARLTON MEREDITH, geologist and consulting petroleum engineer, formerly of Cisco, Texas, has opened an office in Dallas, Texas.

FREDERICK G. CLAPP, consulting geologist of New York City, has a paper entitled "Oil Concessions in the Middle East" in the February, 1933, issue of *Mining and Metallurgy.*

HANS HEUSSER, geologist and formerly of Basel, Switzerland, is now in Madrid, Spain. He may be addressed at Conde Peñalver 15.

Arnold S. Bunte, geologist for the Shell Petroleum Corporation, has been transferred from Houston, Texas, to Iowa, Louisiana.

Delmer L. Powers, formerly chief geologist of Hudson's Bay Oil and Gas Company, Calgary, Canada, has been transferred to the Rocky Mountain Division of the Continental Oil Company at Denver, Colorado. His address is 1040 Continental Oil Building.

David Glynn Jones and Charles Edmund Wood are authors of a paper, "A Contribution to the Study of Oil-Field Water Analysis," published in the October, 1932, issue of the *Journal of the Institution of Petroleum Technologists*.

Russell V. Johnson, consulting geologist of Calgary, Alberta, Canada, is now in Vancouver, and may be addressed at 960 Jervis Street.

Homer A. Noble, formerly in the geological department of the Shell Petroleum Corporation, Houston, Texas, has opened offices in the Sterling Building at Houston where he will do consulting work.

A. J. Bauernschmidt, Jr., formerly of Salt Lake City, Utah, is now with the Union Sulphur Company and may be addressed at Sulphur, Louisiana.

Joseph J. Zorichak, geologist for the Stanolind Oil and Gas Company, has been transferred from Denver, Colorado, to Tulsa, Oklahoma.

An Oil Equipment and Engineering Exposition will be held at Dallas, Texas, April 17–23, 1933. The location is the Machinery Building at the Texas State Fair Grounds. For further information, address the Dallas Chamber of Commerce, Dallas, Texas.

Announcement has recently been made by the National Research Council of Canada of the resumption of plans for holding the Fifth Pacific Science Congress, postponed from last year. This Congress will be held in Victoria and Vancouver, British Columbia, between the dates of June 1 and 14, 1933. Following the sessions excursions will be arranged through the western part of Canada. Further information may be obtained from H. E. Gregory, chairman, committee on Pacific investigations, National Research Council, Washington, D.C.

President Frederic H. Lahee spoke before the West Texas Geological Society at San Angelo, February 7, his subject being "The Affairs of the Association." This is the fifteenth group of Association members to whom he has spoken on this subject.

John R. Klep, graduate mining engineer of the University of Louvain, Belgium, and now at the University of Oklahoma, Norman, spoke before the Tulsa Geological Society, February 6, on the subject, "Structural Geology of, and Production Methods in, the Moreni Oil Fields of Roumania." Following this paper, M. M. Kinley, of Tulsa, showed his motion pictures of extinguishing an oil well fire in the Moreni field.

Cecil V. Hagen is geologist for the firm of Orr and Johnson, Fort Worth, Texas, and at present is located at Laredo, Texas. His address is Box 674.

W. A. Clark, Jr., is doing independent work along the Conroe trend and has headquarters at Box 24, Livingston, Texas.

GEORGE SHEPPARD, who recently left Ecuador for Hull, England, has a paper entitled, "Outlines of Ecuadoran Geology," in the February, 1933, issue of the *Pan-American Geologist*, pp. 45-56.

R. C. CONKLING, who has been district geologist for the Shell Petroleum Corporation, San Angelo, Texas, has been transferred to the division offices of the company at Houston, Texas.

Nearly two hundred students and friends attended the dedication of the portraits of CHARLES N. GOULD, director of the recent Oklahoma Geological Survey, and CHARLES E. DECKER, professor of paleontology, held in the ballroom of the Student Union Building on the campus of the University of Oklahoma at Norman, February 8, 1933. Short talks by friends and former students included: IRVING PERRINE, presiding; R. L. CLIFTON, "Dr. Gould's Services to the State"; GUY WILLIAMS, "Dr. Gould as a Teacher"; ROY HADSELL, "Dr. Gould as a Pioneer"; J. T. RICHARDS, "Dr. Decker's Service to the State"; C. L. COOKSEY, "Dr. Decker as a Teacher"; and JERRY B. NEWBY, "Dr. Decker's Services to The American Association of Petroleum Geologists." On behalf of the University, president Bizzell accepted the portraits, which will be hung in the library of the Geology Building.

The Fort Worth Geological Society of which R. H. FASH, of the Fort Worth Laboratories, Box 1008, Fort Worth, Texas, is secretary-treasurer, and PAUL L. APPLIN is president, has presented the following programs at its Monday noon luncheons at the Worth Hotel this year.

"Experiences of a Mining Engineer in the Federated Malay States," by E. B. KIMBALL.

"Ideas Relative to Evaluating Petroleum Properties," by FRANK A. HERALD.

"History of the Discovery of the Pledger Dome, Brazoria County, Texas," by R. R. THOMPSON.

"Geology of the Van Field," by R. A. LIDDLE.

"General Geological Reconnaissance in Northern Ontario, Canada," by FORD BRADISH.

"Geology and Oil and Gas Development in Ector County, Texas," by S. H. CASTEEL.

"General Geological Reconnaissance in South and Central America," by V. E. EKHOLM.

"Heavy Minerals and Their Use in Correlation Problems," by C. D. CARDRY.

"Kelsey Dome, Texas," by A. R. DENISON.

The San Antonio Section of the Association presented the following technical program at its annual meeting at San Antonio, Texas, February 17 and 18, 1933.

"The Importance of the Oil Industry to Southwest Texas," by IKE S. KAMPMANN.

"Résumé of Oil and Gas Development in Southwest Texas during 1932," by I. K. HOWETH.

"The Value of Gas Conservation and Efficient Use of a Natural Water Drive as Demonstrated by Laboratory Models," by H. D. WILDE, Jr.

"Producing Horizons of the Texas Gulf Coast," by ALEXANDER DEUSSEN.

"The Pettus Sand of Southwest Texas," by AL. FERRANDO.

"Surface and Subsurface Relationships of the Yegua, Jackson and Frio Formations in Southwest Texas," by FRED P. SHAYES.

"Plug-Back Work in the Salt Flat Oil Field, Caldwell County, Texas," by R. E. WATSON.

"The Carolina-Texas and Laurel Fields of Webb County, Texas," by DON DANVERS and OLIN G. BELL.

"The Driscoll Ranch Pool of Duval County, Texas," by I. R. SHELDON.

"A Subsurface Study of Ordovician Stratigraphy of West and Southwest Texas," by HENRY MORGAN.

"Subsurface Conditions in Southeastern Edwards Plateau Area," by JOSEPH M. DAWSON.

"Deep Well Correlations Along the Balcones Fault Zone," by SAM H. HOUSTON, Jr.

"The Purpose and Methods of Field Work in Southwest Texas of the Water Resources Division of the U. S. Geol. Survey," by W. N. WHITE.

Secretary-treasurer CHARLES A. STEWART reported that approximately 250 persons attended the meeting. The formal opening of the new geological museum and library of the San Antonio Geological Society at 526 Milam Building was announced. On Saturday morning the geologists visited the laboratories of the Edgar Tobin Aerial Surveys. At night 150 persons attended the dinner-dance.

Officers elected for the new year are: president, L. F. MCCOLLUM; vice-president, FRED P. SHAYES; secretary-treasurer, JULIAN Q. MYERS. The past-president, ED. W. OWEN, continues as a member of the executive committee, and DILWORTH S. HAGER is the fifth member of the committee. JOSEPH M. DAWSON is the San Antonio district representative on the Association business committees of 1934 and 1935.

The Petroleum Geologists of Strasbourg (Groupe du Géologues Pétroliers de Strasbourg) have elected the following officers for 1933: president, Ch. R. HOFFMANN; treasurer, R. SCHNAEBELE; secretary, J. JUNG, 2, rue Boussingault, Strasbourg, France.

President LAHEE has appointed the following delegates to represent the Association at the Sixteenth Session of the International Geological Congress at Washington, D. C., and on the field trips: ALEXANDER DEUSSEN, of Houston, Texas; FRANK W. DEWOLF, of Urbana, Illinois; JAMES H. GARDNER, of Tulsa, Oklahoma; RALPH D. REED, of Los Angeles, California; and L. C. SNIDER, of New York.

Professor W. H. HAAS is serving as acting chairman of the department of geology and geography at Northwestern University.

Recent visiting lecturers before the department of geology and geography, Northwestern University, included: T. A. HENDRICKS, of the United States Geological Survey, "The Classification of Coal;" L. E. WORKMAN, of the Illinois Geological Survey, "Subsurface Methods as Applied to Illinois;" C. W. WASHBURNE, consulting geologist of New York, "Structural Studies in the Oregon Coast Ranges;" G. R. MANSFIELD, of the United States Geological Survey, "Viewpoints in Geological Research;" and E. S. BASTIN, of the University of Chicago, "Ores of Copper Lean in Iron and Sulphur."

LESLIE A. FISHER, geologist for the Sinclair Prairie Oil Company, is stationed at Conroe, and H. SMITH CLARK, geologist for the same company, is stationed at Fort Worth, Texas. Items about these men in the February *Bulletin* were erroneous.

REX W. MCGEHEE, formerly assistant on the Oklahoma Geological Survey and the Geological Survey of Illinois, talked before the Tulsa Geological So-

ciety on the subject, "Pennsylvanian Cycle of Illinois and its Significance," February 20.

Robert Roth, formerly with the Indian Territory Illuminating Oil Company at Bartlesville, Oklahoma, has moved to Paonia, Colorado, for the summer.